→ Kim Domptail | December 3, 2025

POTW x Hydrogen Nexus

How do we Power the Utilities of the Future?

Clean Water SoCal

Welcome

Agenda

1. Introduction
   - H_2 101
   - Why H_2

2. Current H_2 trends
   - Market update
   - California focus

3. H_2 x WRRF
   - Water → H_2
   - Biogas → H_2
   - Biosolids → H_2
   - Ammonia → H_2
   - H_2 storage & microgrids
   - Air emissions

Introduction

→ H_2 101

Why H_2

Hydrogen 101

First element of opportunity

- Most common element in the universe
- Always bonded to other elements such as oxygen and carbon* → Must be produced
- Energy carrier, not an energy source
- Versatile applications

Energy content:

- Highest energy content by mass. Ex: 3x gasoline
- Low energy content by volume. Ex: 1/4 gasoline, 1/3 natural gas

Safety considerations:

- Used in the industry for decades (refineries, fertilizer, rocket fuel)
- H_2 is hard to detect: colorless and odorless, H_2 flames nearly invisible in daylight
- Wide flammability range and low ignition energy → H_2 venting is key || H_2 disperses 3x as fast as natural gas
- Small molecule → metal embrittlement

* “Natural Hydrogen,” or molecular hydrogen present in the earth’s subsurface, is currently considered uneconomical to extract.

The Present

- World 100 Mt H_2/yr | US 10Mt H_2/yr
- 99% of H_2 from natural gas, coal & other HC
- World H_2 production emits 980 $MtCO_2$/yr
- 90% of H_2 used for HC refining & fertilizer production

The Future

- Transition to **low-emissions H_2** in current industries
- Adoption of H_2 in **new sectors**: transport, heavy industry, energy storage & grid balancing
- Improvement in **cost-competitiveness**
- **Export** market for geographies with excess energy

Hydrogen Production Pathways

GEOLOGIC HYDROGEN

- Naturally occurring geologic hydrogen

  white H_2

- Bio-based sub-surface conversion

  gold H_2

FOSSIL RESOURCES

- **Natural Gas:**
  - SMR *(2/3 of current H2 production globally)* — **gray** H_2
  - SMR or ATR with CCUS — **blue** H_2
  - eSMR / microwave reforming — **teal** H_2
  - Methane pyrolysis — **turquoise** H_2
- **Coal:**
  - Gasification (bituminous / lignite) *(20% of current H2 production globally)* — **black brown** H_2
  - Gasification with CCUS — **blue** H_2

BIOMASS / WASTE

- **Via AD & biogas**
  - Reforming
  - Pyrolysis
- **Thermal treatment**
  - Pyrolysis
  - Gasification
- **Biological**
  - Fermentation (dark or light)
  - Microbial electrolysis

  dark green H_2

WATER SPLITTING

- **Water electrolysis** powered by:
  - Renewables — **green** H_2
  - Nuclear — **pink** H_2
  - Electric grid — **yellow** H_2
- Electrolysis types:
  - Low-temperature (Alkaline, PEM, AEM)
  - High-temperature (SOEC)
- Other long-term water splitting pathways:
  - **Thermochemical**
  - **Photobiological**
  - **Photoelectrochemical**

OTHER FEEDSTOCKS

- **Ammonia**
  - Reforming
  - Electrolysis
- **(Bio-)Methanol**
  - Reforming

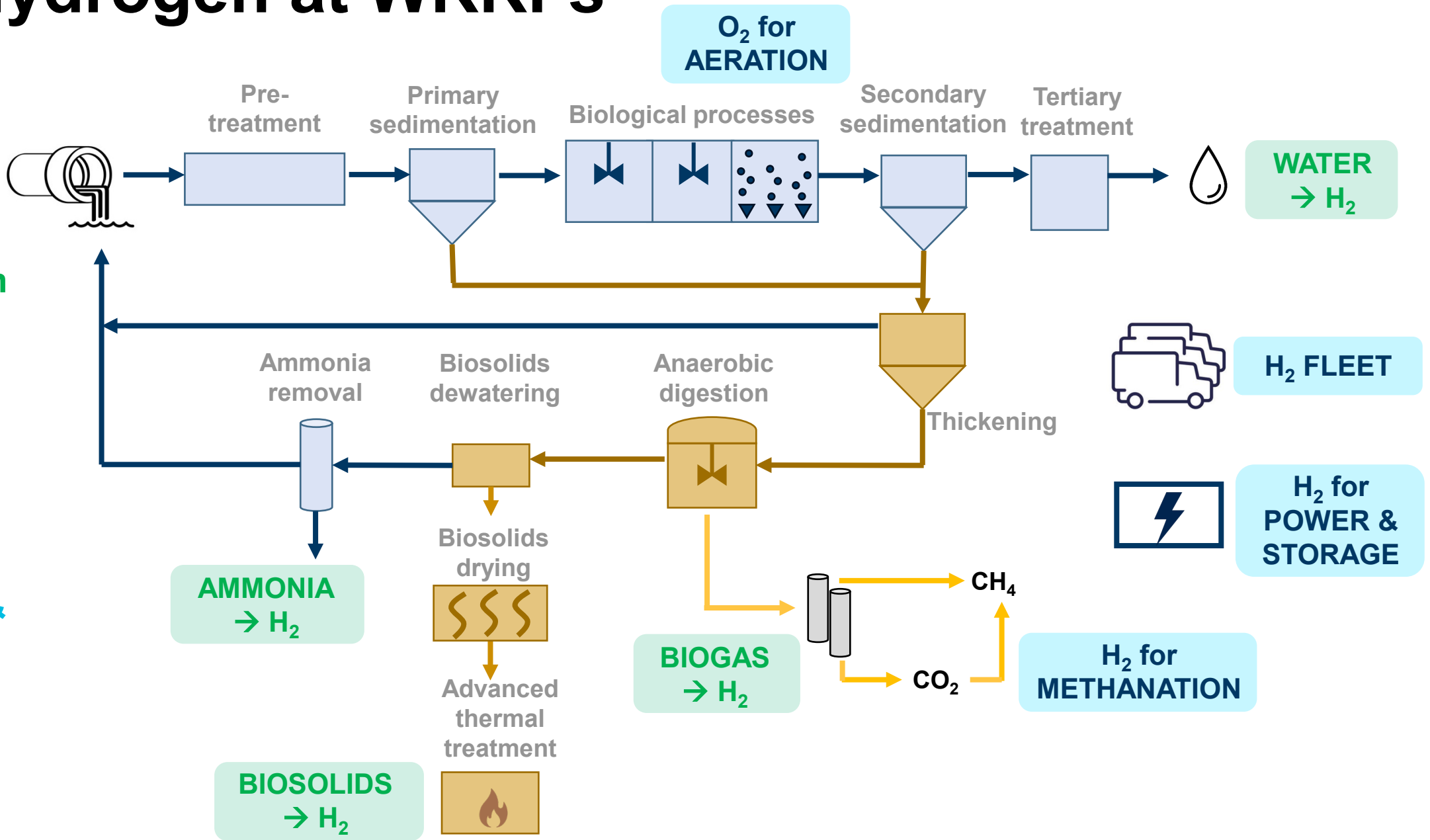
Why Hydrogen at WRRFs

1

Production of hydrogen

2

Use of hydrogen & byproduct



Current Hydrogen Trends

→ **Market Updates**

California Focus

Global Low-Emissions Hydrogen Market

RECENT NEGATIVE NEWS

- CA & PNW H2 Hub funding canceled
- 50+ projects publicly canceled recently

ENERGY POLICY

US Department of Energy to Cancel All Hydrogen Hub Grants, Leaked Documents Reveal

By Fuel Cells Works
October 8, 2025 at 8:38 AM EDT

The Guardian US

Fortescue axes two green hydrogen projects after Trump administration's shift on renewables

H2VIEW

Woodside Energy scraps US green hydrogen project

By Edward Laity on Jul 23, 2025

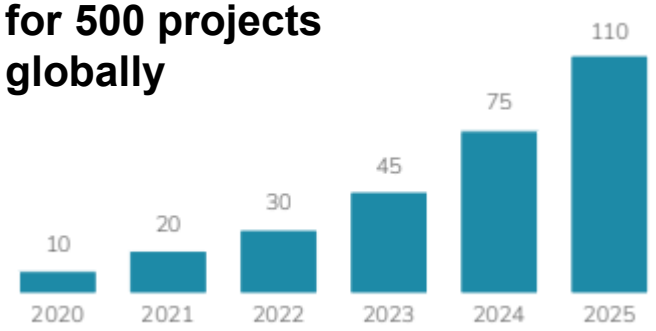
Reuters

IEA cuts 2030 low-emissions hydrogen production outlook by nearly a quarter

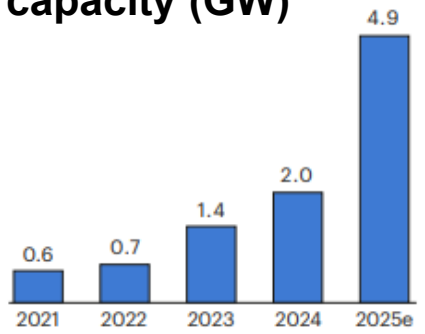
By Reuters
September 12, 2025 9:40 AM PDT · Updated September 12, 2025

BUT

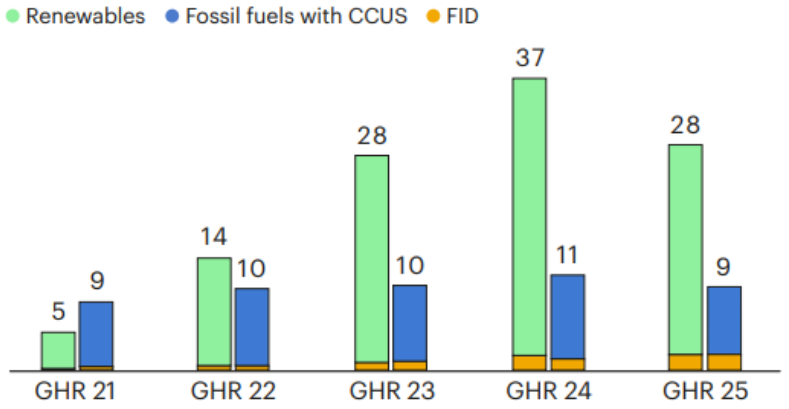
$110 billion committed for 500 projects globally



Electrolyzer installed capacity (GW)



Low-emissions H_2 production from announced projects by 2030 (Mt/yr)



2030 forecast reduced by 24% but still 37 Mt/yr of low emissions H_2

U.S. Policies and Funding Updates

IIJA Hydrogen Hubs Status

IRA Tax Credits

IRS Code	Description	OBBBA Update
45V	Clean Hydrogen PTC (up to 3 $/kg)	Need to start construction by 12/31/27
45Y & 48E	Clean Electricity PTC and ITC	Wind + Solar: begin construction by 7/4/26 or placed in service by 12/31/27 Other technologies: pre-OBBBA deadlines and phase-out apply
45Q	CCUS Tax Credit	$85/ton CO_2 for sequestration, use or EOR ($180 for DAC)

Hydrogen's Key Role for California Net Zero

2022 CARB Scoping Plan for Achieving Carbon Neutrality

CARB SB 1075 comprehensive report on hydrogen due soon

Production

H_2

1,700x
renewable hydrogen

End uses

- 100% light-duty vehicle sales are ZEV by 2035
- 100% medium and heavy-duty vehicles sales are ZEV by 2040
- 20% of **aviation** fuel demand is met by electricity (batteries) or hydrogen (fuel cells) in 2045.
- 25% of ocean-going **vessels** utilize hydrogen fuel cell electric technology by 2045.
- **Port operations**: 100% of CHE is zero-emission by 2037.
  100% of drayage trucks are zero emission by 2035.
- Line haul and passenger **rail** rely primarily on hydrogen fuel cell technology.
- **Chemicals / Pulp & paper**: Hydrogen for 25% of process heat by 2035 and 100% by 2045
- Renewable hydrogen **blended** in fossil gas pipeline at 7% energy (~20% by volume)

HYDROGEN FUEL CELL PARTNERSHIP

- 19,000 fuel cell cars
- 51 retail H_2 stations
- 66 fuel cell buses
  (AC Transit, OCTA, SunLine)
- 4 truck H_2 stations

CALIFORNIA AIR RESOURCES BOARD

Low Carbon Fuel Standard

Includes Hydrogen pathways

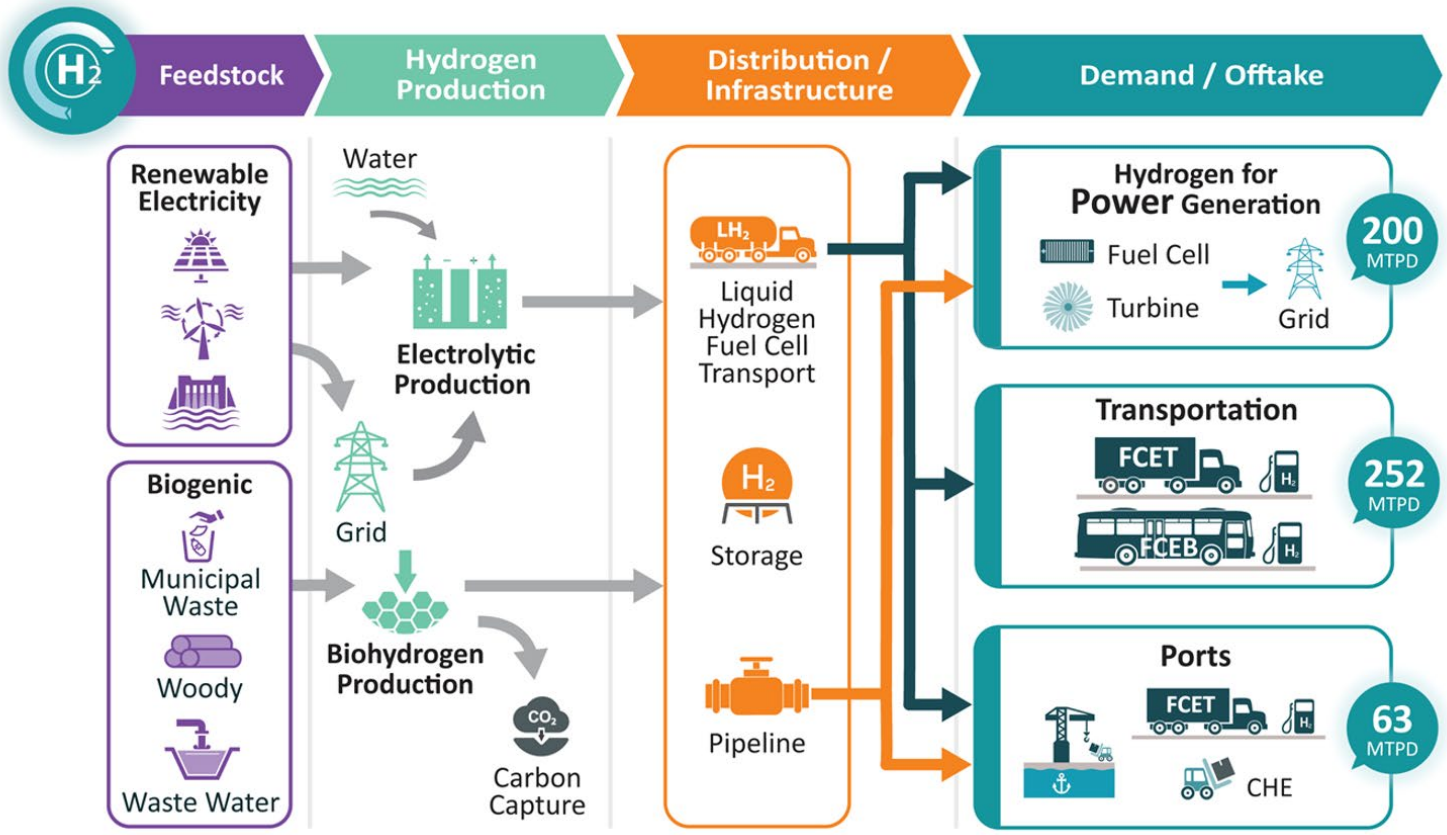
California Energy Commission
50 YEARS OF ENERGY LEADERSHIP

Clean Hydrogen Program

FIRST PUBLIC H2

California Remains Committed to Hydrogen

Renewable Clean Hydr



$11B+ in State and Private Investment

- **Production**: 9 facilities
- **Power**: 2 plants with H_2 capable turbines
- **Transportation**:
  - 1,000 fuel cell electric **buses**
  - 5,000 fuel cell **trucks**
  - 40+ hydrogen **refueling** stations
- 3 **port** infrastructure upgrades
  - 190 CHE
  - 10 mobile refuelers
  - 800 fuel cell trucks
- New hydrogen **pipelines**

Hydrogen x WRRFs Opportunities

→ **Water to Hydrogen**

Biosolids to Hydrogen

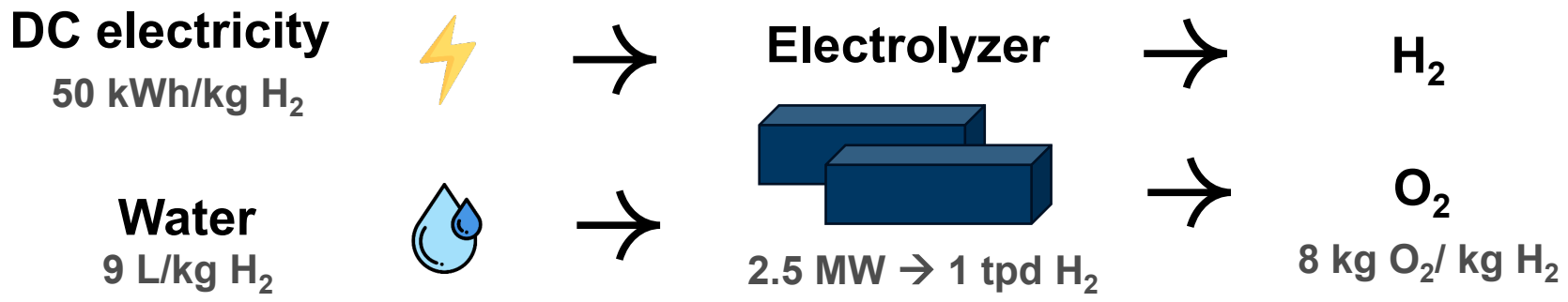
Biogas to Hydrogen

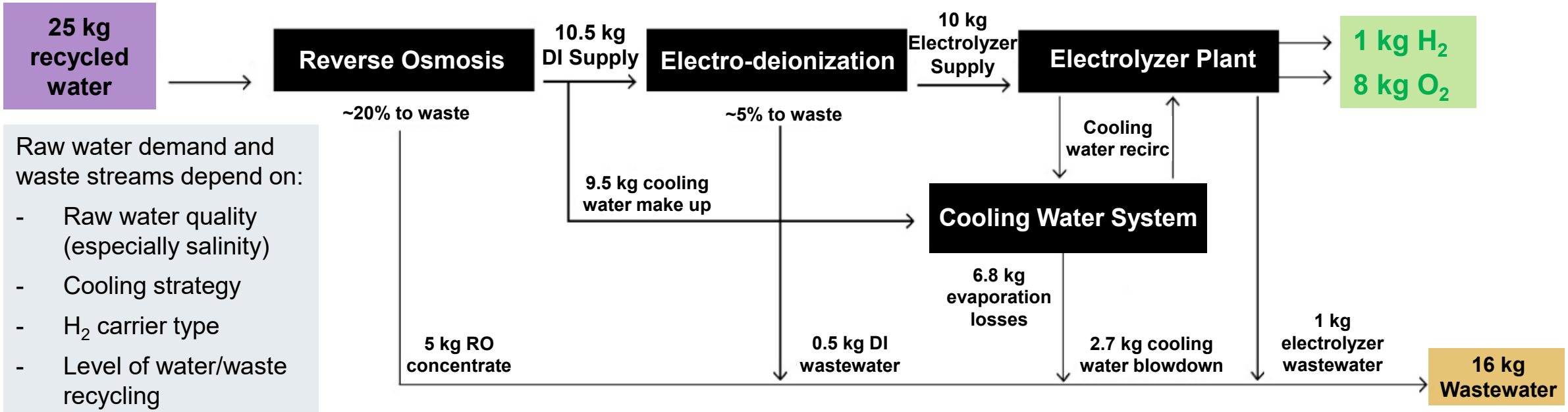
Ammonia to Hydrogen

Hydrogen Storage

Hydrogen Microgrid

Water Electrolysis



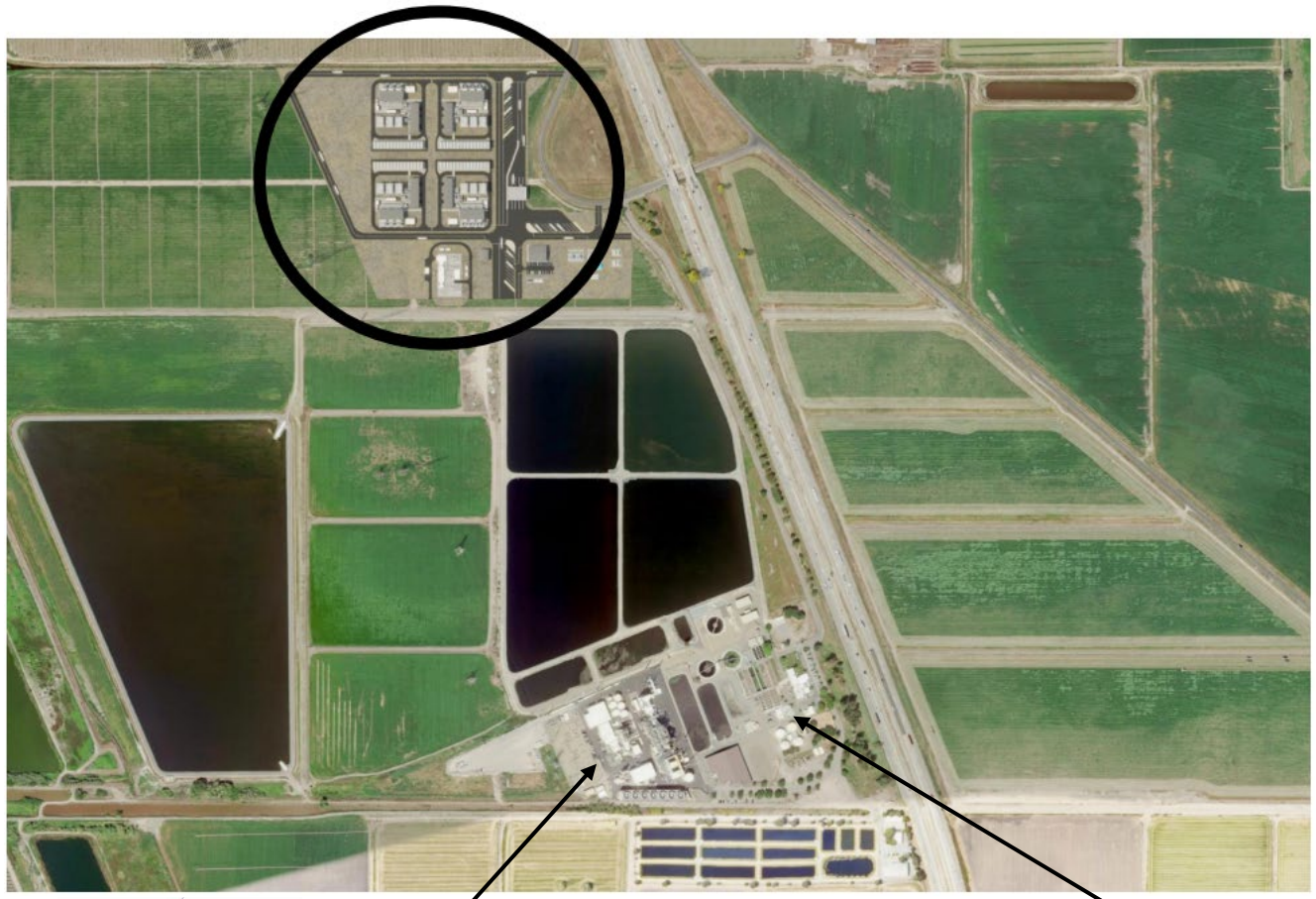


Raw water demand and waste streams depend on:

- Raw water quality (especially salinity)
- Cooling strategy
- H_2 carrier type
- Level of water/waste recycling

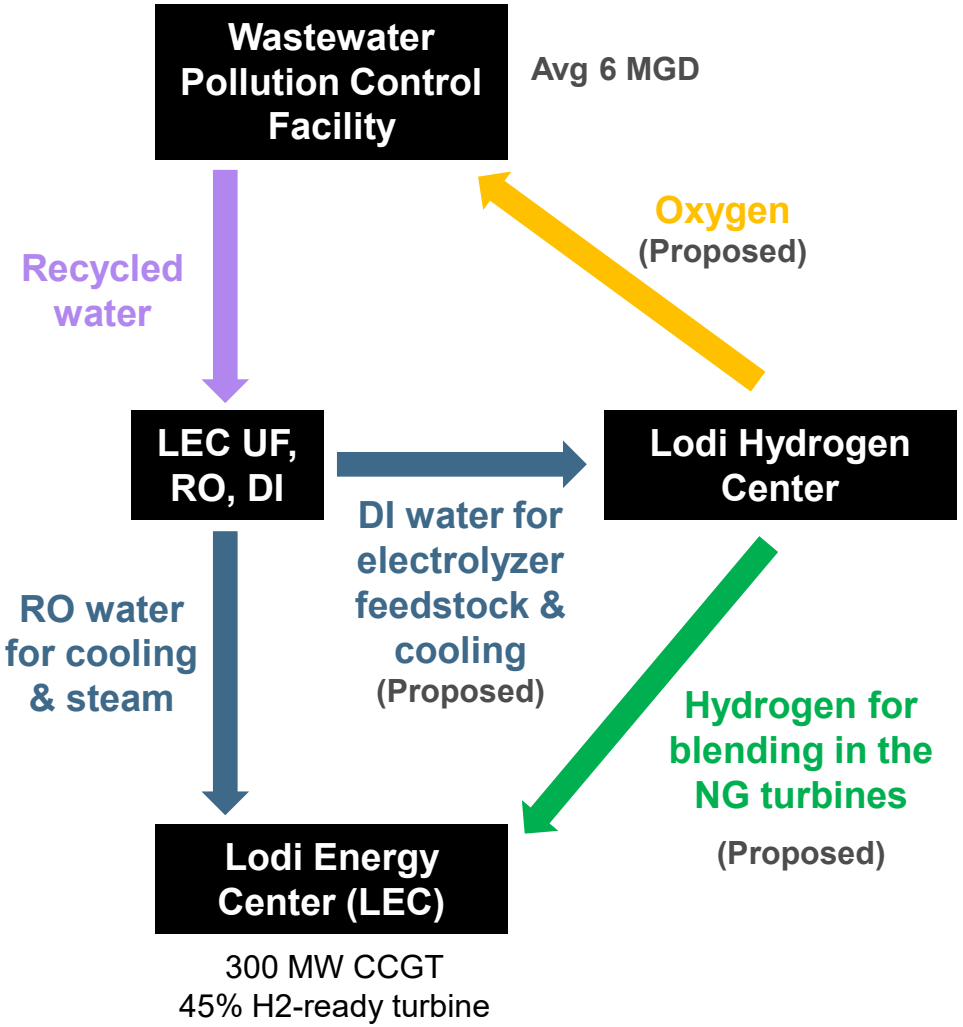
Co-locating H2 with Recycled Water

Lodi Hydrogen Center



Lodi Energy Center

White Slough Wastewater Pollution Control Facility



Biosolids Gasification

Various biosolids advanced thermal treatment projects, focused on volume reduction and PFAS destruction. Can be energy neutral.

Example of operational projects:

Aries Linden Biosolids Gasification Facility, NJ

Logan Water Biosolids Gasification Facility, Australia

Bioforcetech Silicon Valley Clean Water Pyrolysis Facility, CA

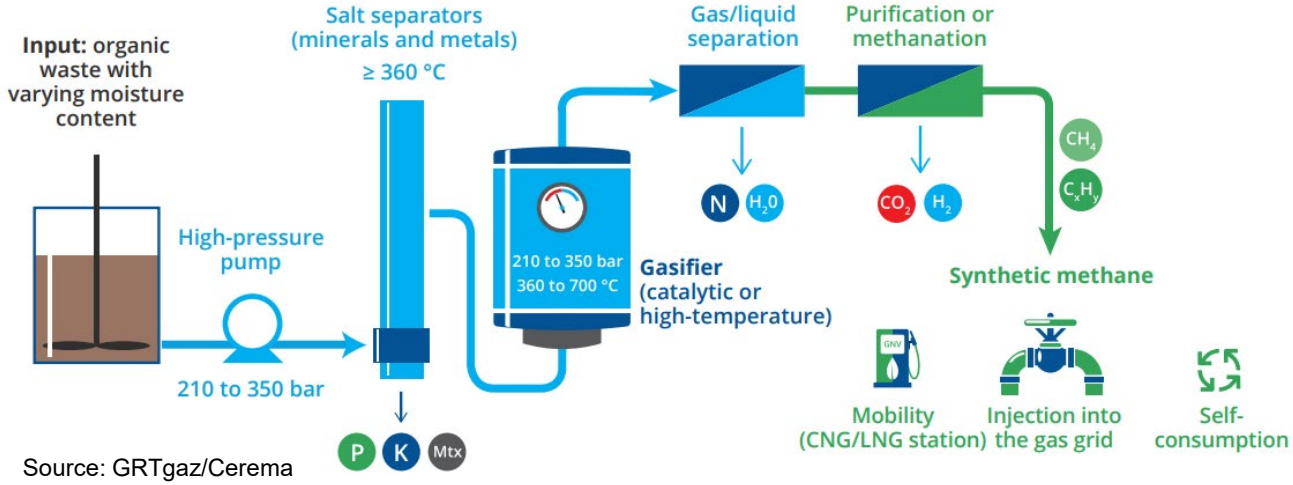
Ecoremedy gasification at Edmonds WWTP, PA

Ephrata Biodrying & Pyrolysis, PA

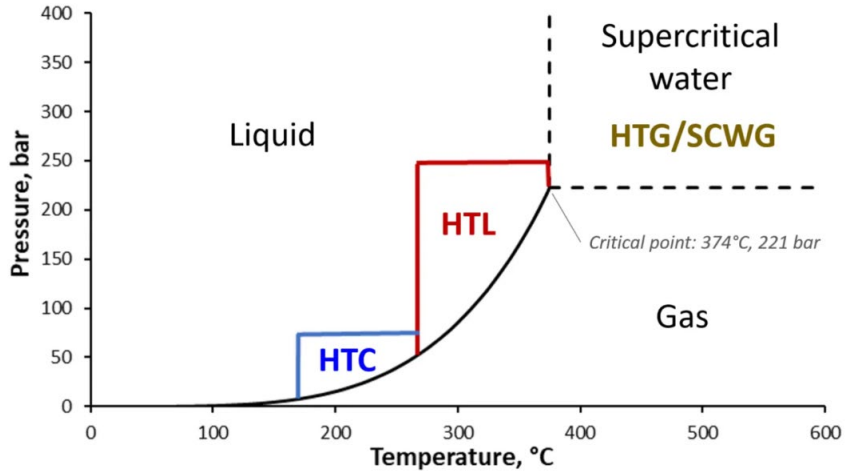
→ Syngas in TOX with heat recovery for biosolids drying

New advanced thermal treatment technologies
net energy positive

Hydrothermal gasification (high T, high P) for wet organic waste (no need for drying) produces syngas (CH_4, H_2, CO_2)



Source: GRTgaz/Cerema



Primary end products:

- HTC → **Hydrochar**
- HTL → **Biocrude-oil**
- HTG → **Syngas**

Biogas Reforming or Pyrolysis to Hydrogen

WWTP Biogas to Hydrogen and Graphite

- Woodman point WWTP in Western Australia (about 43 MGD)
- Commercial demo project: 100 tons H_2 per year and 340 tons of graphite per year
- Pyrolysis with iron ore catalyst

Dairy Biogas to Renewable Fuels

- Biogas reforming in HYCO1 CUBE Technology
- Production of renewable diesel and SAF
- HYCO1 new non-coking catalyst

Dairy Biogas to Hydrogen

- CO_2/CH_4 separation
- CH_4 reforming
- H_2 used for IC and FCEV

<u>Other projects:</u>

- HyGear 250 kW e-SMR producing 400 kg H_2/d from biogas in Germany
- Tecnidas Reunidas operational prototype in Spain (50 kg/d)
- Utility Global (H2Gen) and Maas Energy announced project for dairy digester biogas to hydrogen in California

Ammonia Recovery and Use

Ammonia recovery

- Recover ammonia instead of typical biological treatment converting to inert N_2 gas
- Stripping: Produce a concentrated ammonium sulfate solution
- Other physicochemical treatment: Ion exchange, Membrane

Metro Vancouver case study at Lulu Island and Annacis WWTPs

Ammonia to hydrogen

Thermal cracking OR Electrolysis

current WATER TECHNOLOGIES INC.

- High temperature process with catalyst
- Will enable long distance transport of hydrogen

Ammonia to power

AMOGY

Containerized ammonia cracking to fuel cell or internal combustion engine

Mainspring HYLIION KARNO

Fuel-agnostic linear generators

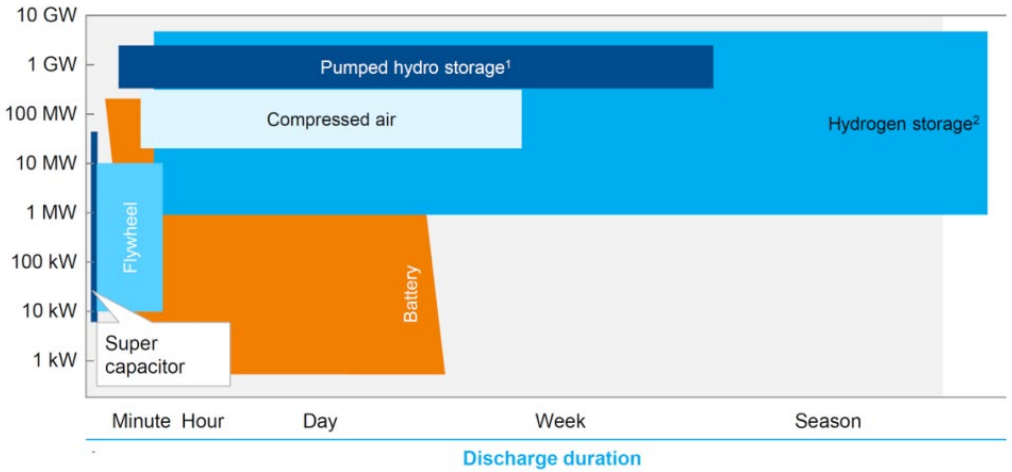
Ammonia to other products

Fertilizer, etc

Hydrogen Storage

Advantages

- **Long-term** energy storage
- High energy content by mass



Source: Hydrogen Europe, 2019

Challenges

- **Costs**
- Low energy content by volume (compared to gasoline, NG)

Hydrogen storage technologies

Hydrogen can be stored in various forms:

PHYSICAL STORAGE

Compressed H2

- **Aboveground pressurized vessels**
- **Subsurface** compressed H_2 storage

Liquid H2

- **Cryogenic liquid H_2** storage vessels

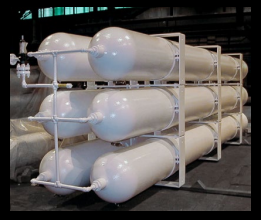
MATERIAL-BASED STORAGE

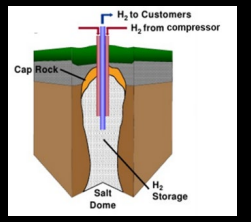
Solid-state storage

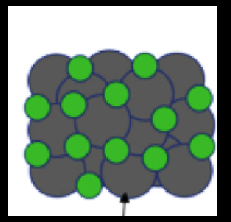
- **Metal hydrides** (absorption)
- **Carbon-based materials** (adsorption)

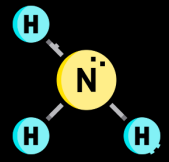
Chemical carriers

- **Ammonia** (NH_3)
- **Methanol** (CH_3OH)
- Liquid Organic Hydrogen Carriers (**LOHC**)









Backup Power and Microgrids

Calistoga Resiliency Center

Batteries + H_2 Fuel Cells Microgrid

ENERGY VAULT®
Enabling a Renewable World

PG&E Pacific Gas and Electric Company®

plug™

- 5,000-person community
- Replaced diesel generators (PSPS events)
- 8.5 MW / 293-MWh, 48-hrs
  - Li-ion **battery** for immediate power & black start (7.7 MW / 11.6 MWh)
  - 6 x H_2 **fuel cells** for extended periods
  - **Liquid H_2 storage** (80,000 gal, 234-ft long tank) Can be refilled while in use
- Small footprint compared to BESS only (<1 acre)

Source: https://www.canarymedia.com/articles/hydrogen/hydrogen-microgrid-calistoga-energy-vault-plug-power-pg-e

Synthetic Natural Gas (SNG)

Various sources of syngas (CO, H_2) or CO_2 and H_2

Methanation

$CO + 3\ H_2 = CH_4 + H_2O$

$CO_2 + 4\ H_2 = CH_4 + 2\ H_2O$

1. Gasification & methanation of syngas (CO, H_2)

Coal or Biomass → Thermal Gasification or Some industrial waste gas → Syngas (CO, H_2)

2. Methanation of CO_2 and H_2

Waste CO_2 from biogas or Captured CO_2 from point sources (CCUS) or air (DAC) → CO_2

Various H_2 production pathways → H_2

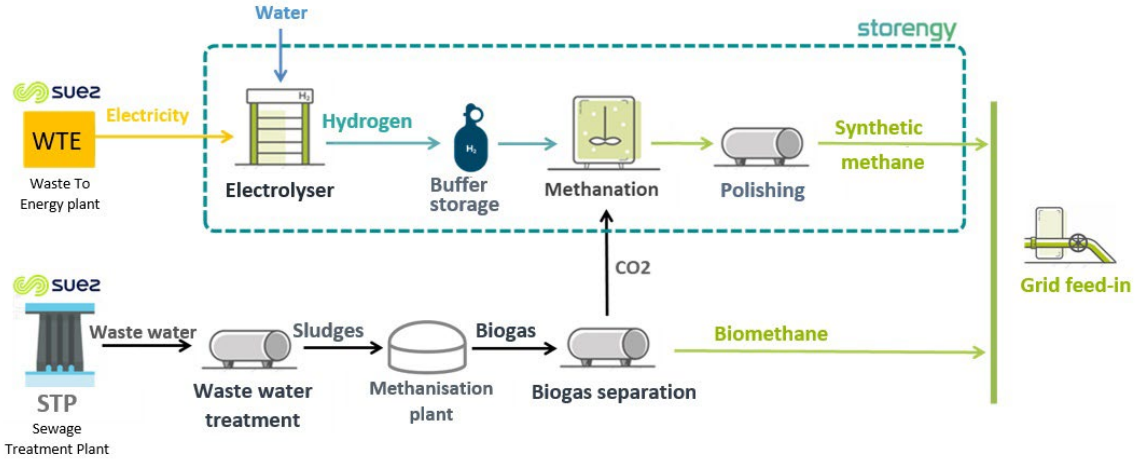
CO_2 + H_2 → e-methane → **SNG**

Denmark

- Digester (~75 farms) → Biogas
- Wind → Green H_2
- CO_2 from biogas is reacted with H_2 to produce CH_4
- Increase methane production by ~50%

France

- Pau-Lescar WWTP "Biofactory"
- Catalytic methanation to convert CO_2 from biogas and H_2 into SNG



Air Emissions from Combustion of H_2 Fuels

In general, when compared to NG and other HC fuels, H_2 combustion:

- Decreases CO_2 emissions
- Decreases CH_4 emissions
- Decreases emissions of other CACs since H_2 do not directly contribute to CO, PM, SOx, etc.
- **Potentially increases NOx emissions**

When blending in industrial equipment (e.g., boilers):

- NOx emissions generally expected to increase
- Key mechanism: thermal NOx formation
- < 30% H_2 generally ok.
- > 30% H_2 material impact and requires additional control measures.

NOx controls exist and are well-established, off-the-shelf solutions:

(1) Control NOx formation

Control combustion temperatures and avoiding hot spots to mitigate **thermal NOx** formation in the combustion zone

- Ultra low-NOx burners (BACT), dry low-NOx, etc
- Adaptive fuel controls to control fuel flow
- Flue gas recirculation (FGR)
- Water/steam injection

(2) Post-combustion controls

Remove NOx from flue gas streams

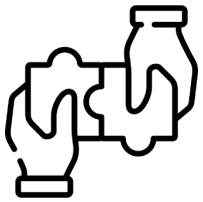
- Selective Catalytic Reduction (SCR)
- Selective non-catalytic reduction (SNCR)
- Scrubbers

↳ Combination of techniques (e.g., low-NOx burner + SCR) can achieve 2-3ppm NOx

Key Messages

H2 Market

1. Low-carbon hydrogen market is growing despite roadblocks (slower trajectory).
2. California remains committed to low-carbon hydrogen.



H2 x WRRF Opportunities

3. Various technologies to leverage WRRF resources to:
   - ✓ Produce low-emission hydrogen or other products (e.g., methanol, SAF)
   - ✓ Use hydrogen (e.g., energy storage) or other by-product (oxygen)
4. Opportunities depend on specific use case / location: resources available, potential partners, nearby offtakers, etc

* Thank you

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