MN R2E Committee Meeting

Emerging Tech- Hydrogen Production at WRRFs

Brendan Wolohan, PE

Senior Engineer

Courtesy of Luna Rossa Prada Pirelli – Hydrogen Support Vehicle

17 October, 2024

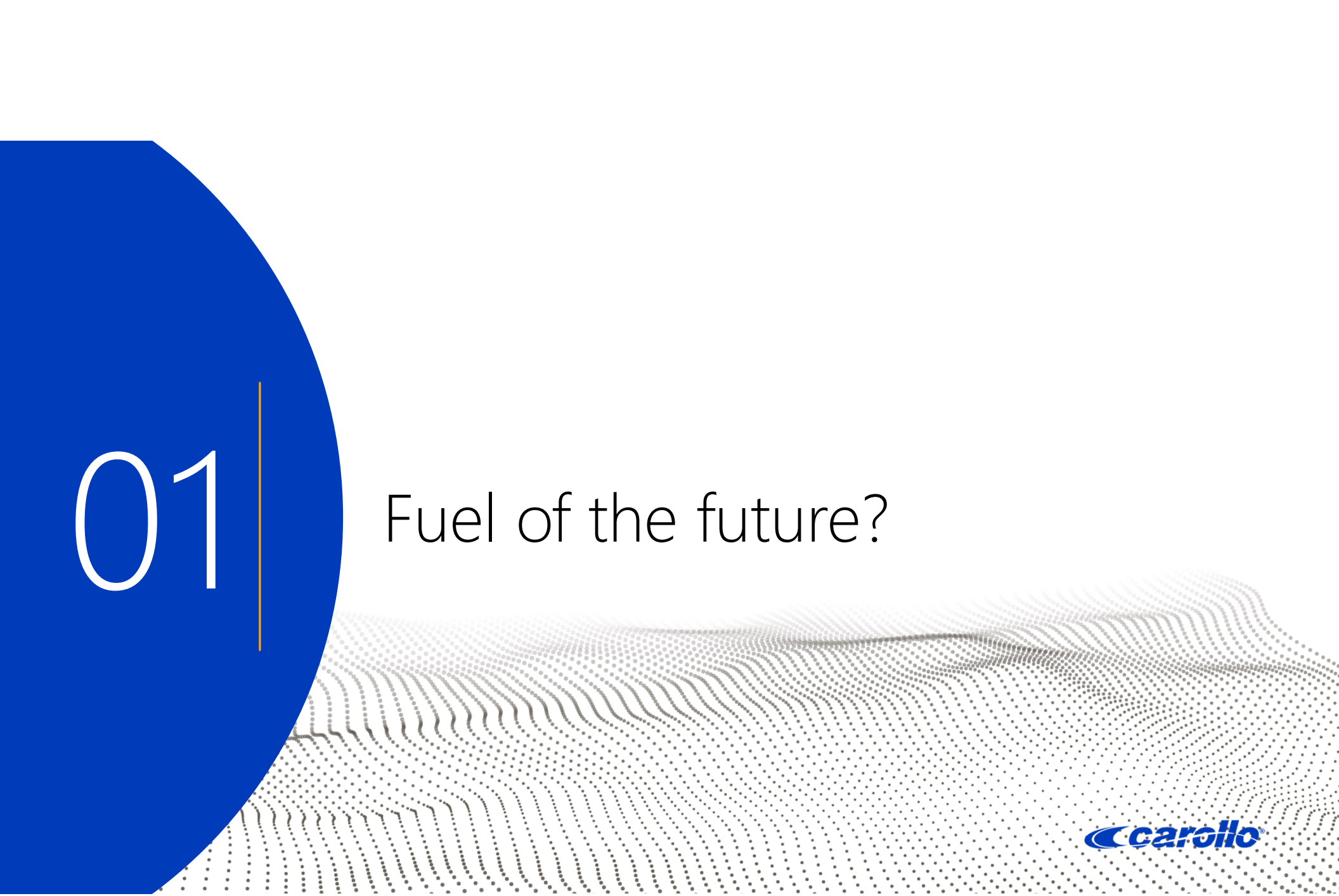
carollo

Agenda

- Hydrogen – Fuel of the future?
- A tale of two cities
- Challenges and opportunities
- Summary

01

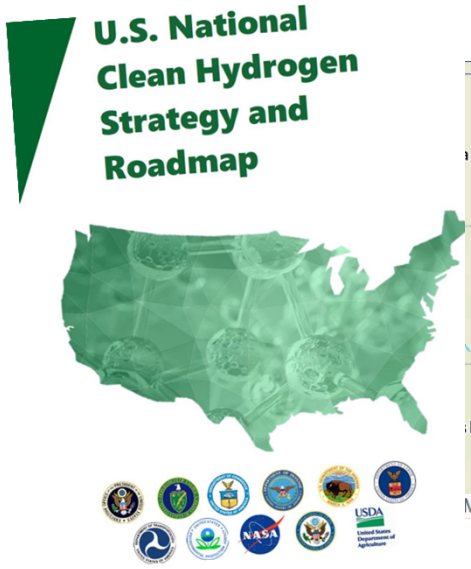
Fuel of the future?

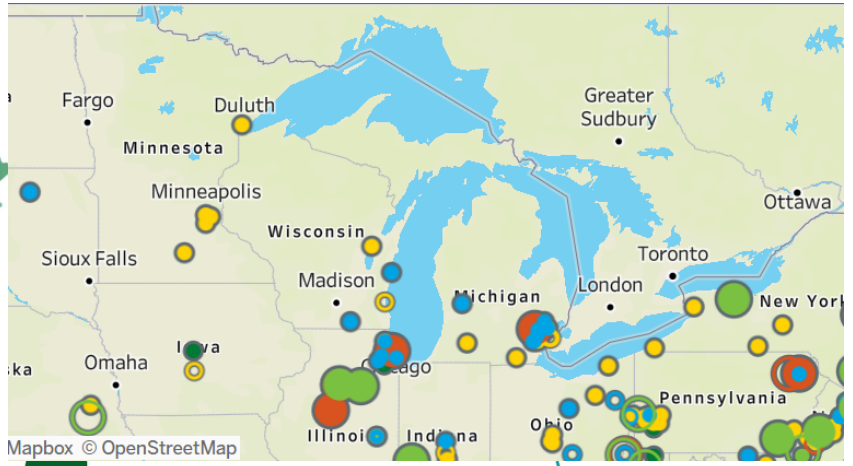


Hydrogen is a hot energy topic!

Bipartisan Infrastructure Law (BIL)

- $1B for Clean Hydrogen Electrolysis Program
- $8B for Regional Clean Hydrogen Hubs
- National Clean Hydrogen Strategy and Roadmap

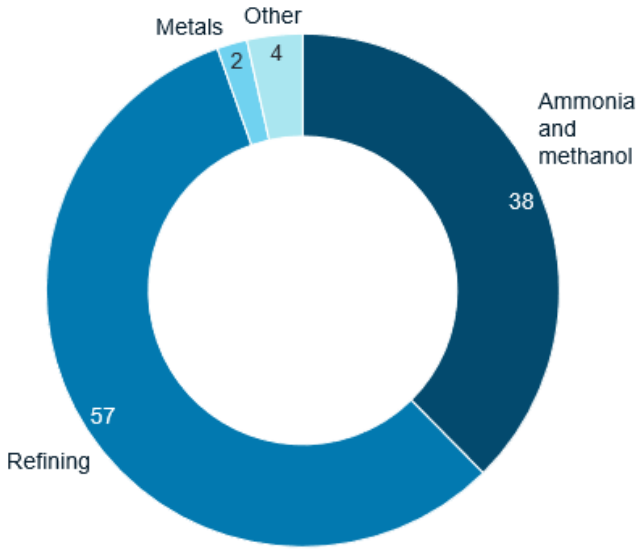




ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Green hydrogen demand increasing

Current US Hydrogen Production:
10 million MT/yr – primarily from fossil fuels



Federal Government Goals:

Enabling 10% Emissions Reductions

2050 — 50 million MT/yr *Clean H_2* by 2050

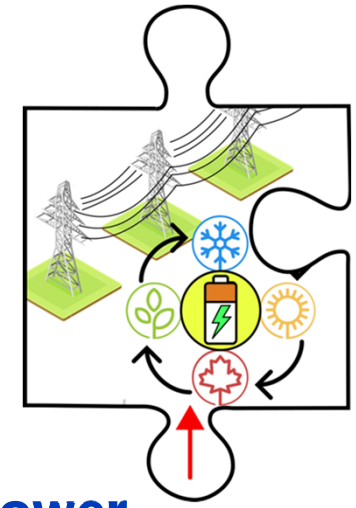
2040 — 20 million MT/yr *Clean H_2* by 2040

2030 — 10 million MT/yr *Clean H_2* by 2030

Target markets for cleaned biogas

Transportation

- Trucks, buses, cars



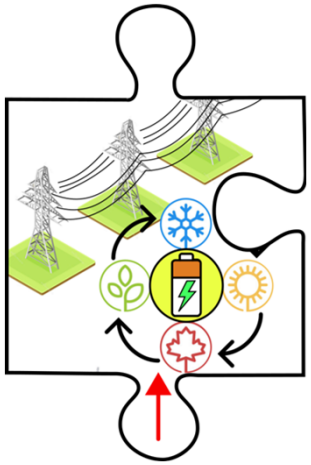
Power

- Cogeneration; blend with natural gas

Target markets for hydrogen

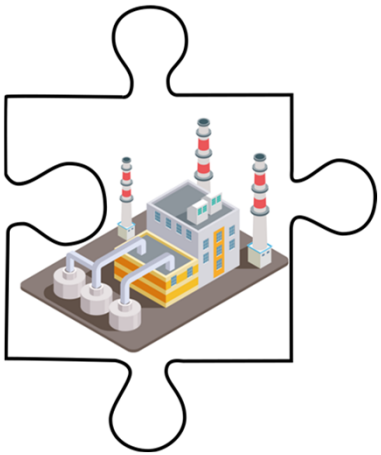
Heavy Transportation

- Trucks, buses, trains, planes, ships



Power

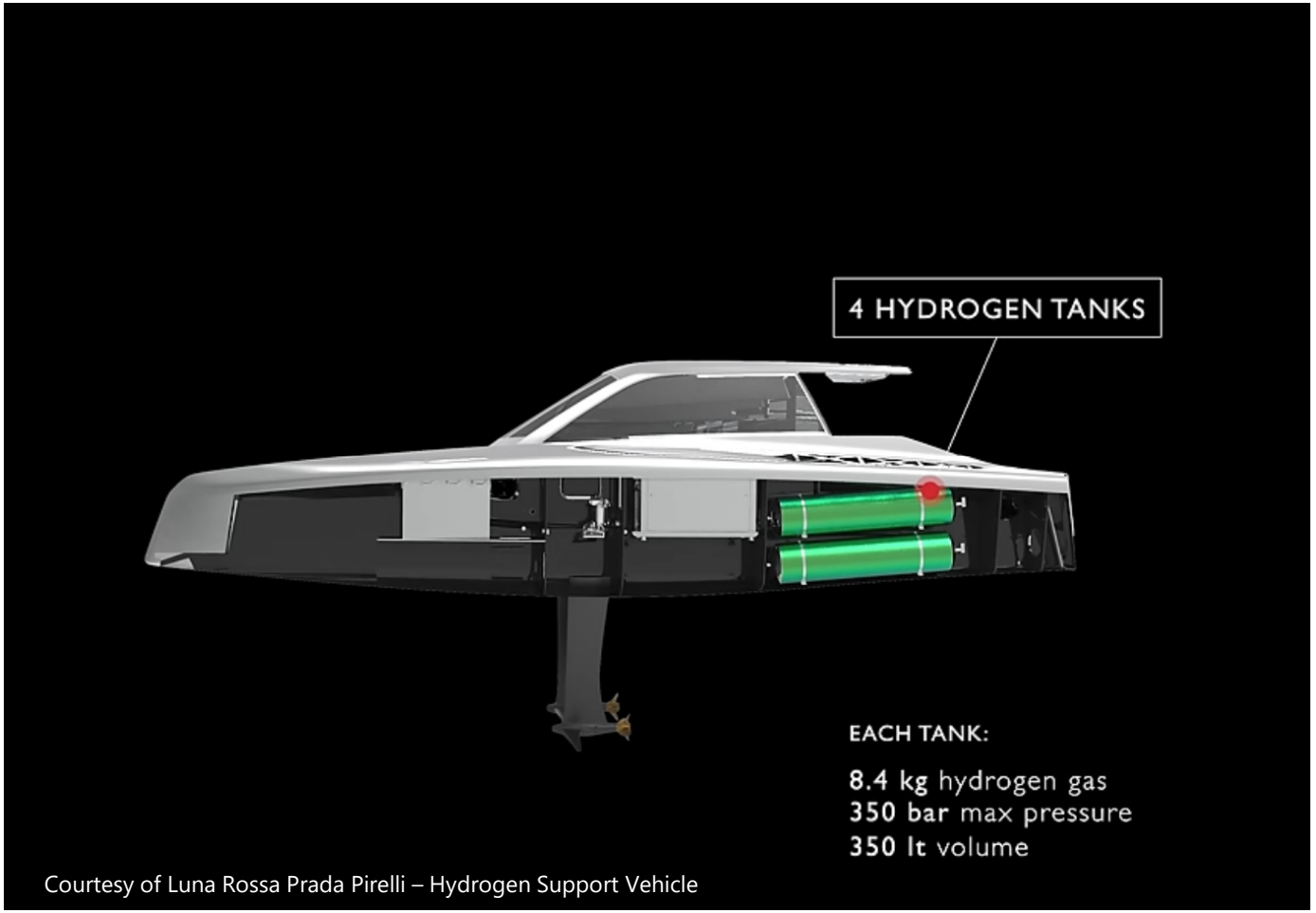
- Fuel cells, backup generators, cogeneration, blend with natural gas



Industrial

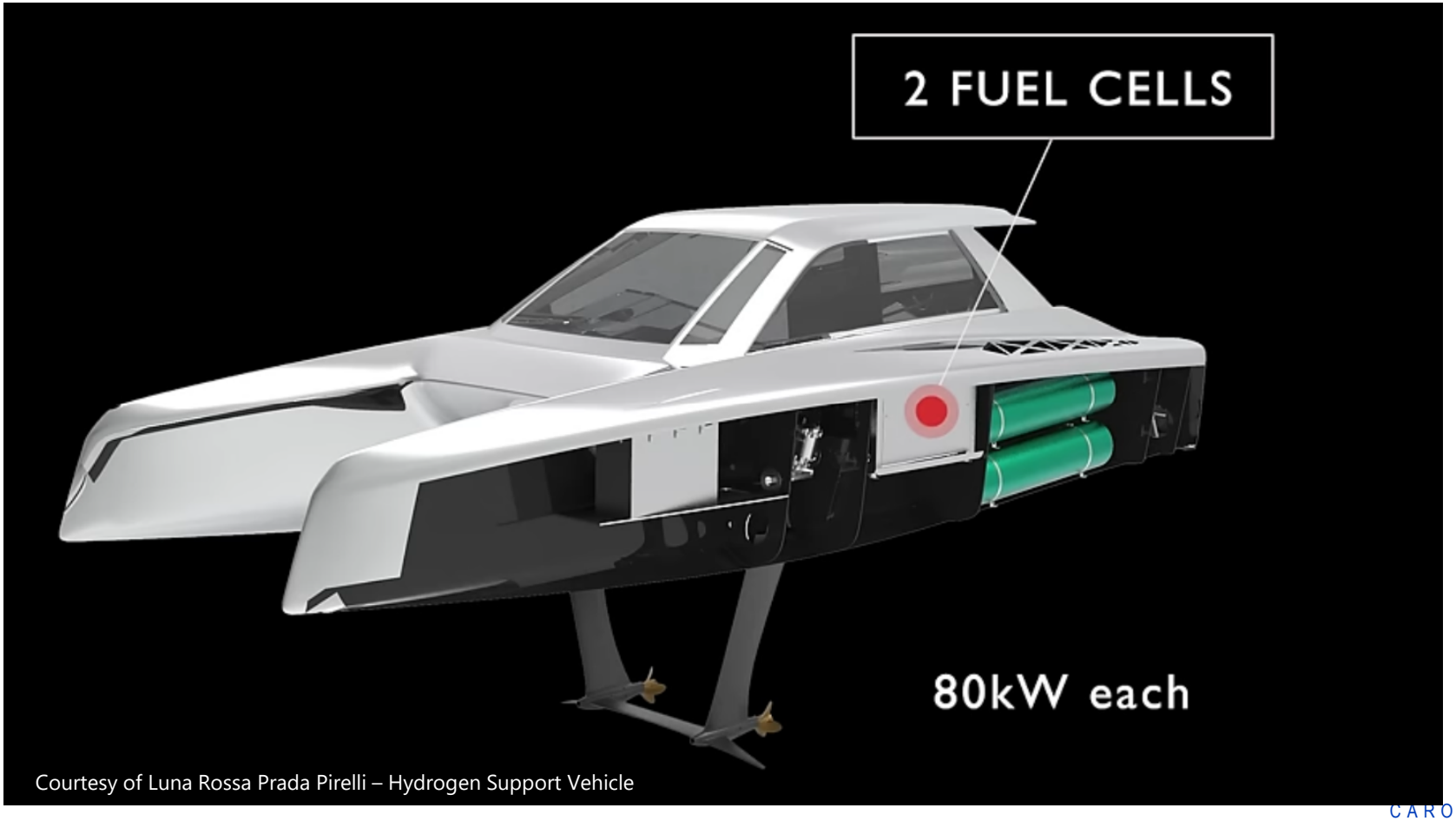
- Boiler heat, furnace heat, steel production, oil refining, chemical production

Hydrogen fuel cell



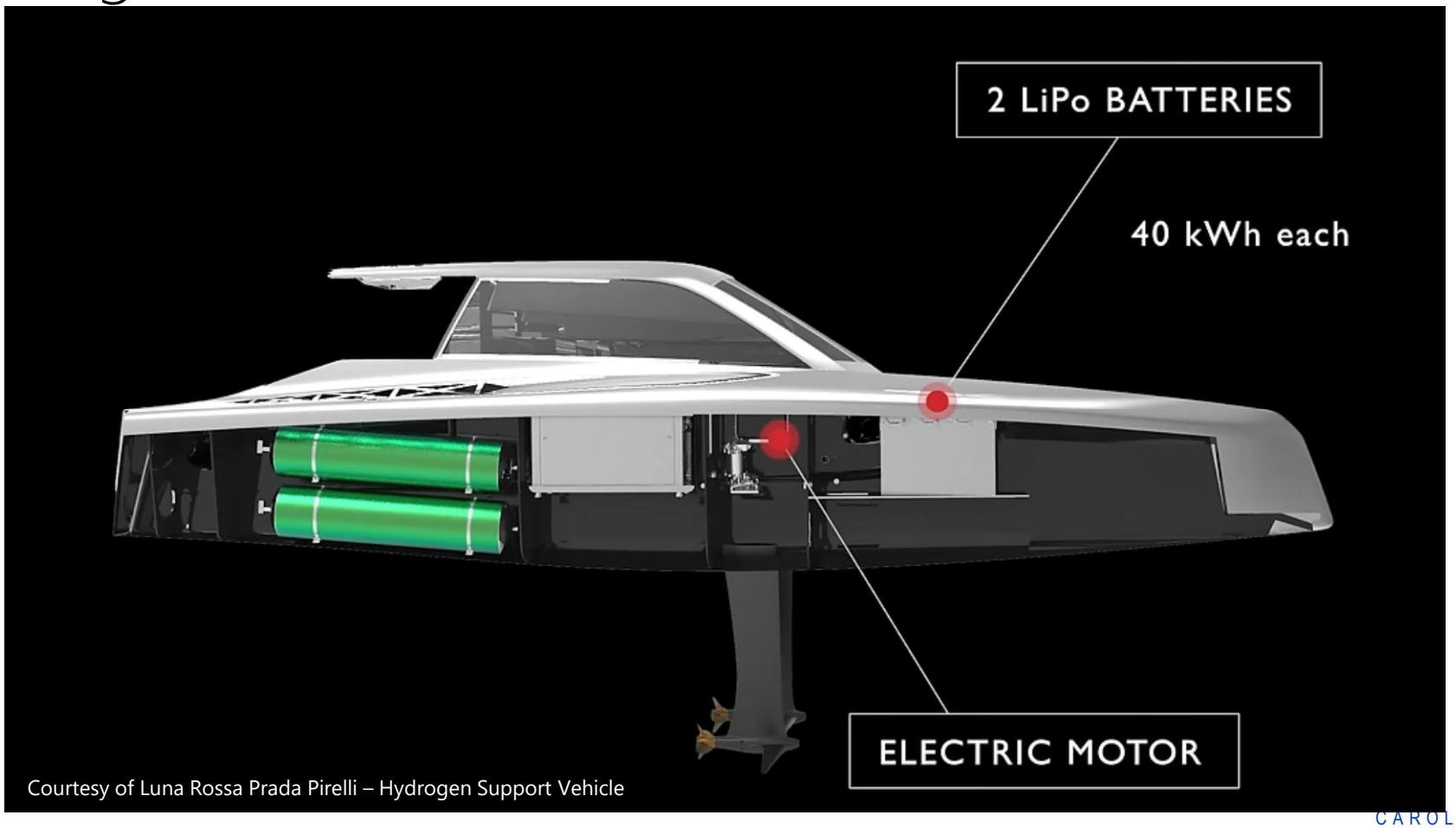
Courtesy of Luna Rossa Prada Pirelli – Hydrogen Support Vehicle

Hydrogen fuel cell



Courtesy of Luna Rossa Prada Pirelli – Hydrogen Support Vehicle

Hydrogen fuel cell



Courtesy of Luna Rossa Prada Pirelli – Hydrogen Support Vehicle

The colors of hydrogen

GREEN

Electrolysis
Splitting of water powered by renewable energy sources

BLUE

Steam Methane Reforming + Carbon Capture and Sequestration
Hydrogen from methane gas with some carbon dioxide capture and sequestration

GRAY

Steam Methane Reforming
Hydrogen from methane gas with not carbon capture; most common approach

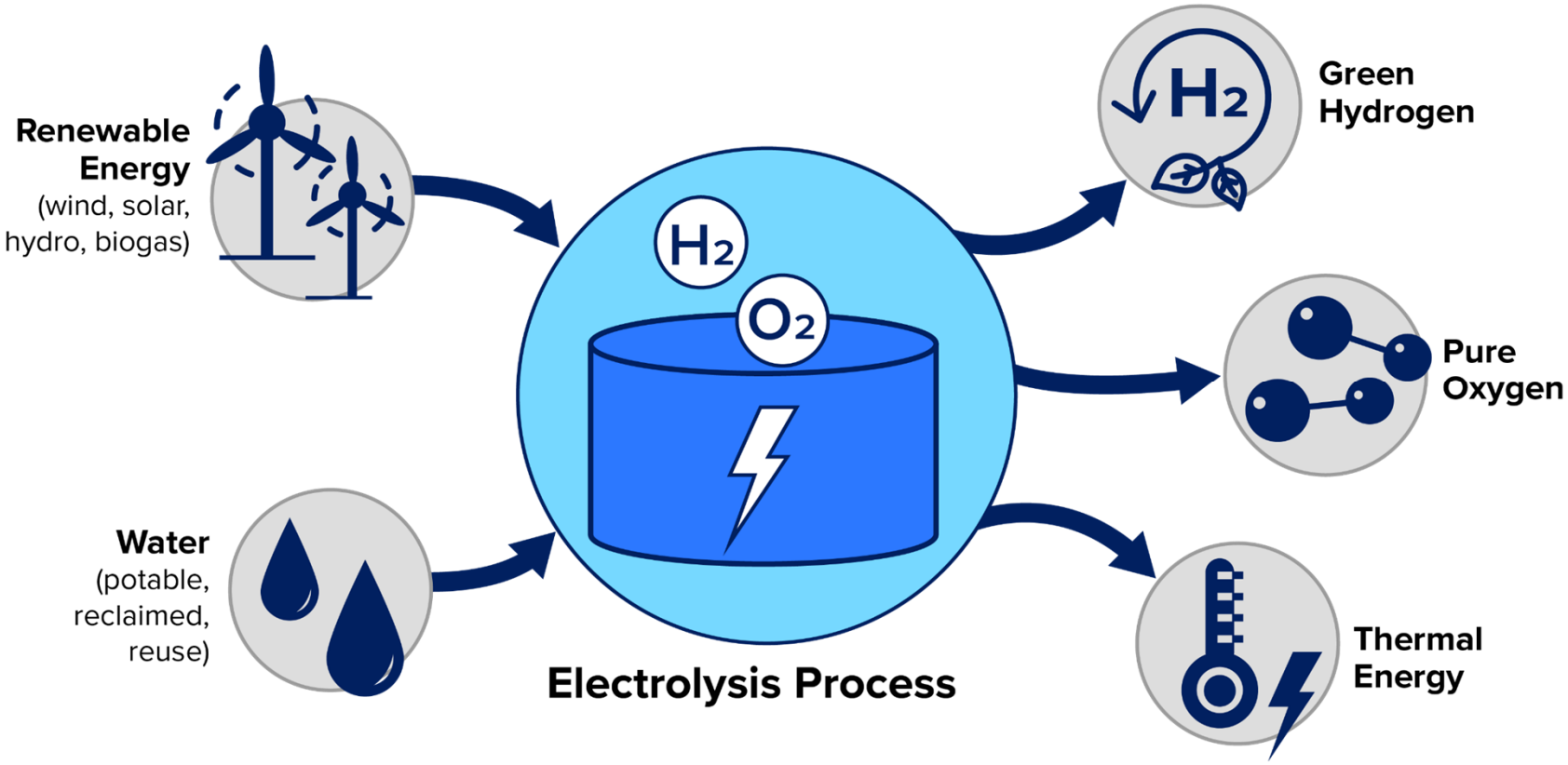
BROWN

Gasification of Coal
Hydrogen from coal/lignite with no carbon capture

PINK

Electrolysis
Splitting of water powered by nuclear energy sources

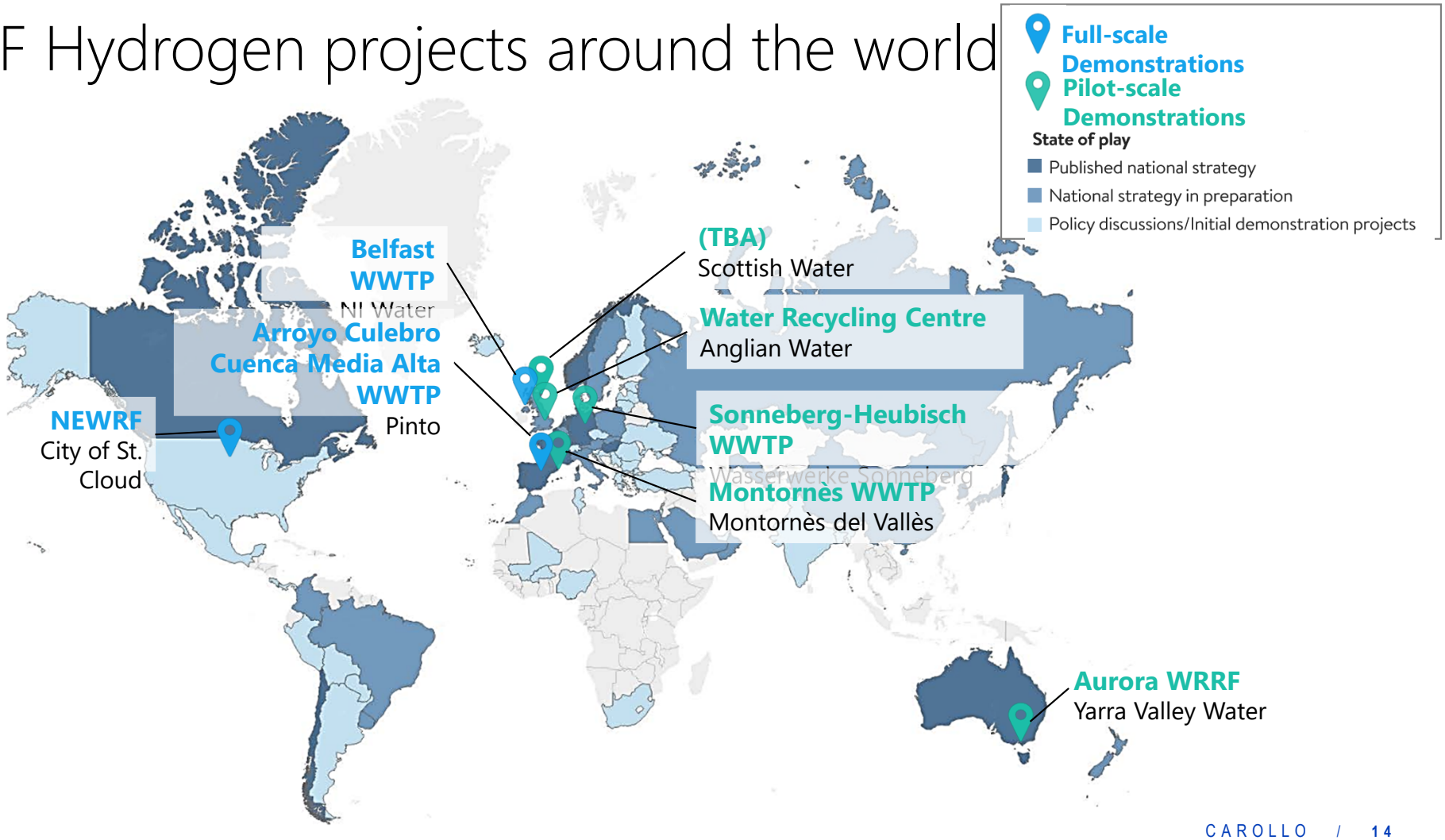
Electrolysis process



Green hydrogen electrolyzers

- **Alkaline Water Electrolysis**
  Over 100 yr old technology; requires extensive support systems and a large footprint; longer start-up and shut down requirements; 5:1 turndown
- **Solid-Oxide Electrolyte Electrolysis**
  Still in development for commercial scale units; operates at high temperatures (900-1600 deg F) so not conducive to frequently cycling; 20:1 turndown
- **Polymer Electrolyte Membrane (PEM) Electrolysis**
  Fastest growing electrolysis technology; quick start and stop operation; 10:1 turndown

WRRF Hydrogen projects around the world



02

Tale of two cities

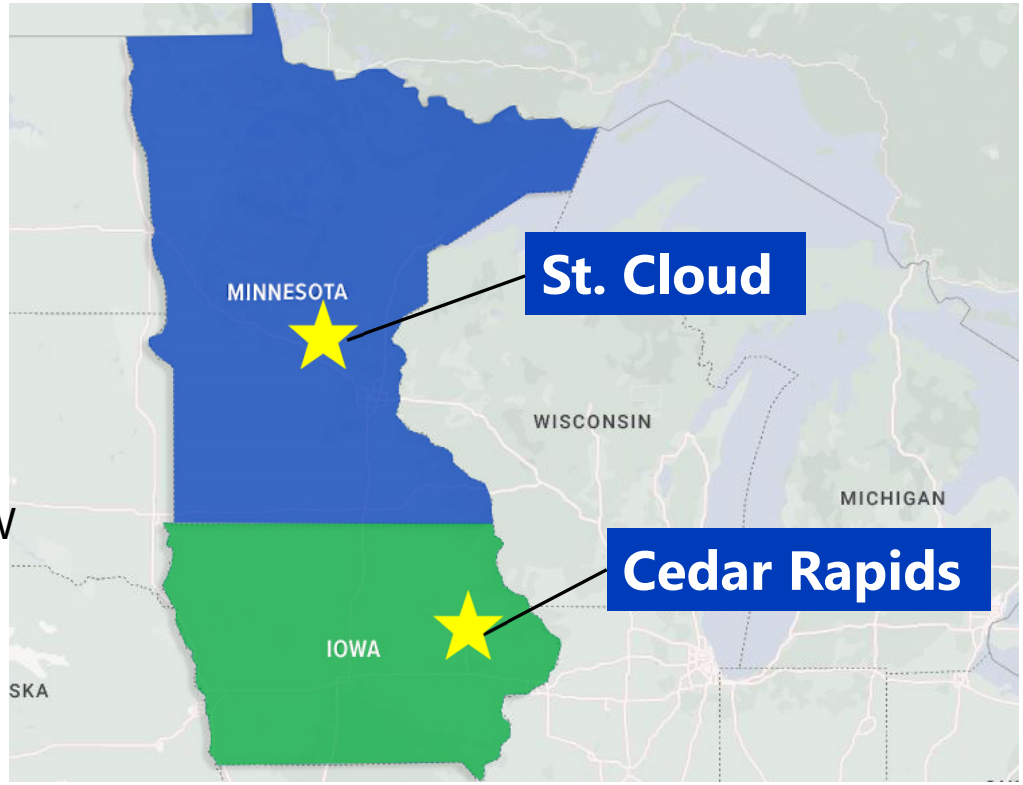
Tale of two cities

St. Cloud, Minnesota

- **Demonstration project** with a 1.25 MW electrolysis system
- Primary focus is decarbonization of community transit

Cedar Rapids, Iowa

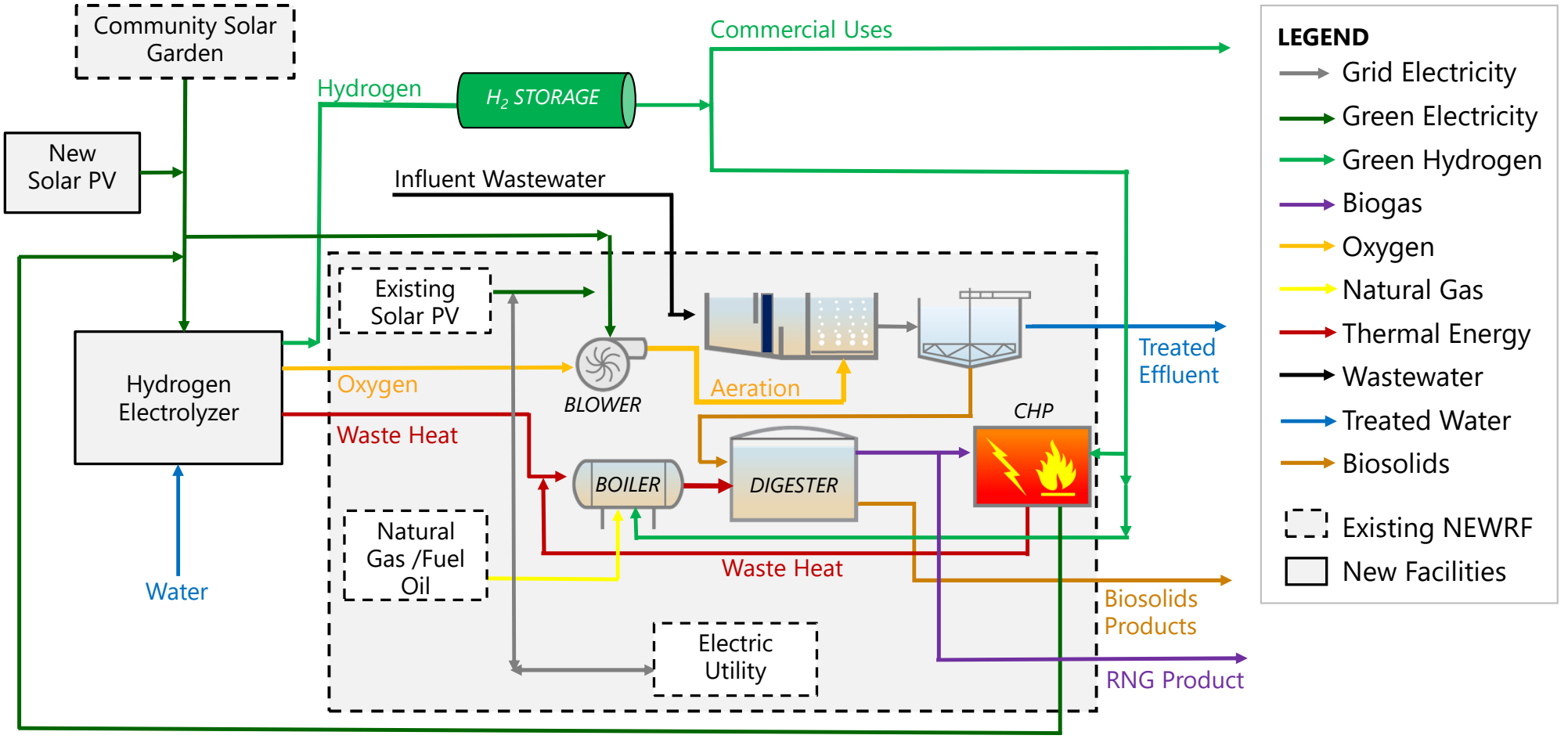
- **Study** for replacement of a cryogenic oxygen production system with a 25 MW electrolysis system
- Primary focus is replacement of an aged 80 tpd pure oxygen production facility



St. Cloud Demonstration Project

- Nutrient, Energy and Water Recovery Facility (NEWRF)
  - » BNR for both nitrogen and phosphorus
- Average Flow: 10.8 MGD
  - » Service population – 120,000
  - » Service for 6 cities
- Energy Neutral:
  - » On-site and community solar farms
  - » On-site combined heat and power (CHP)

St. Cloud Process Flow Diagram



St. Cloud demonstration project overview

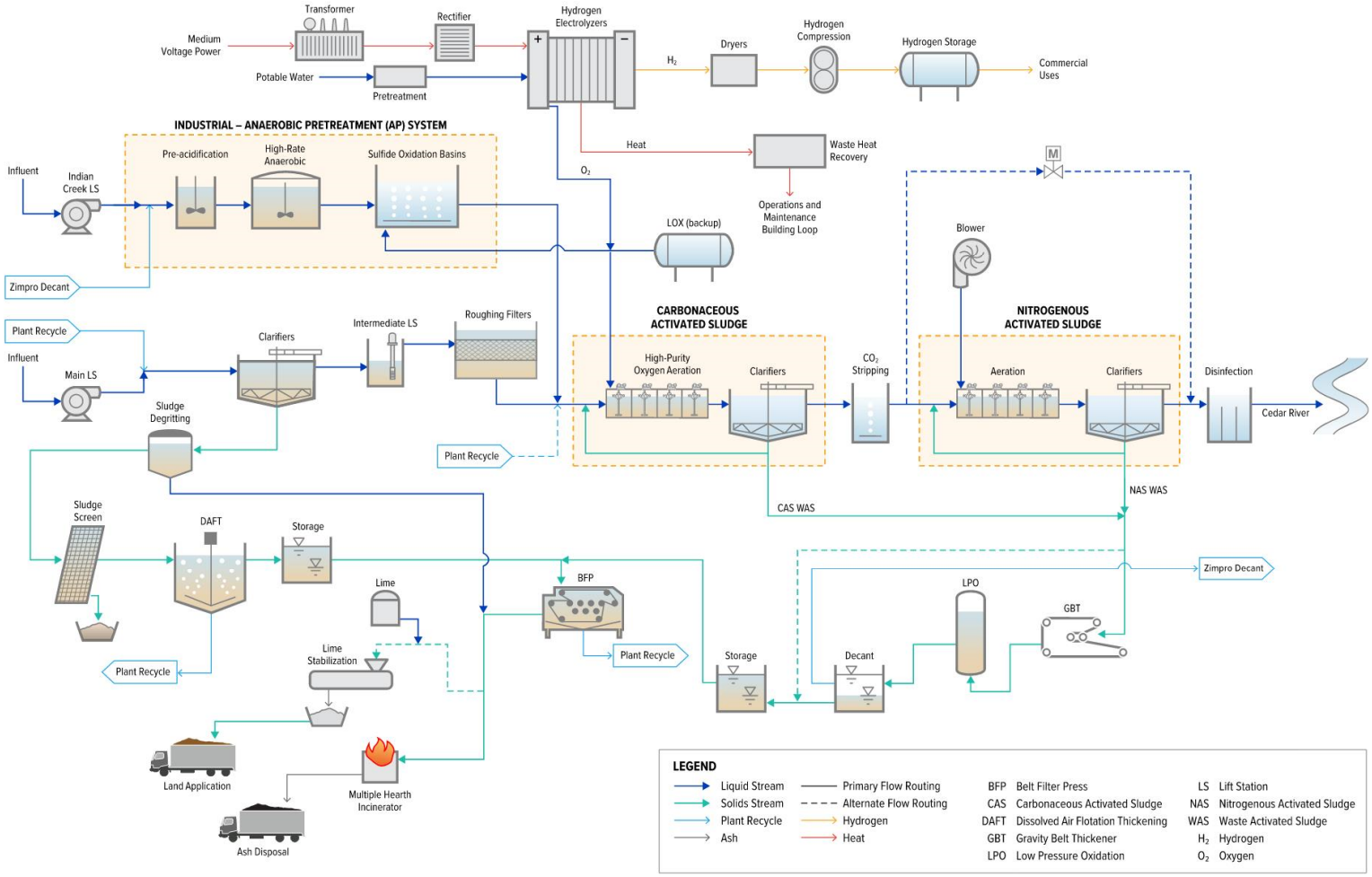
- 1.25 MW PEM Electrolyzer to Demonstrate Viability Production of 531 kg/24 hr (80 tons/yr) of H_2
  - » Sold offsite
- Production of 600 tons/yr of O_2
  - » Onsite utilization
- Production of 23,000 therms/yr of waste heat
  - » Onsite utilization
- 186 gal/hr water consumption

Courtesy of Nel

Cedar Rapids Feasibility Study

- **Secondary Treatment with Partial Nitrification**
  - High-purity oxygen (HPO) for secondary treatment
  - Anaerobic pretreatment for major industrial loads
- **Average Flow:** 40 MGD
  - Approximately 50% of flow is from industrial sources
  - Service population – 180,000
  - Equivalent population – 1.8 million
- **Future Upgrades**
  - Replace anaerobic treatment with AGS
  - Replace Zimpro sludge treatment with THP and anaerobic digestion
  - RNG facility for biogas

Cedar Rapids Process Flow Diagram



Cedar Rapids Project Overview

- 25 MW PEM Electrolyzer System to replace 80 ton/day of cryogenic oxygen production
- Production of 3,400 tons/yr of H_2
  - » Sold offsite
- Production of 28,000 tons/yr of O_2
  - » Onsite utilization
- Production of 1.8 million therms/yr of waste heat
  - » Onsite utilization for building heat

03

Challenges and Opportunities

Challenges for WRRFs

- Green hydrogen markets?
- Renewable energy sources?
- Pure oxygen utilization?
- Waste heat utilization?
- Financing

Target hydrogen markets

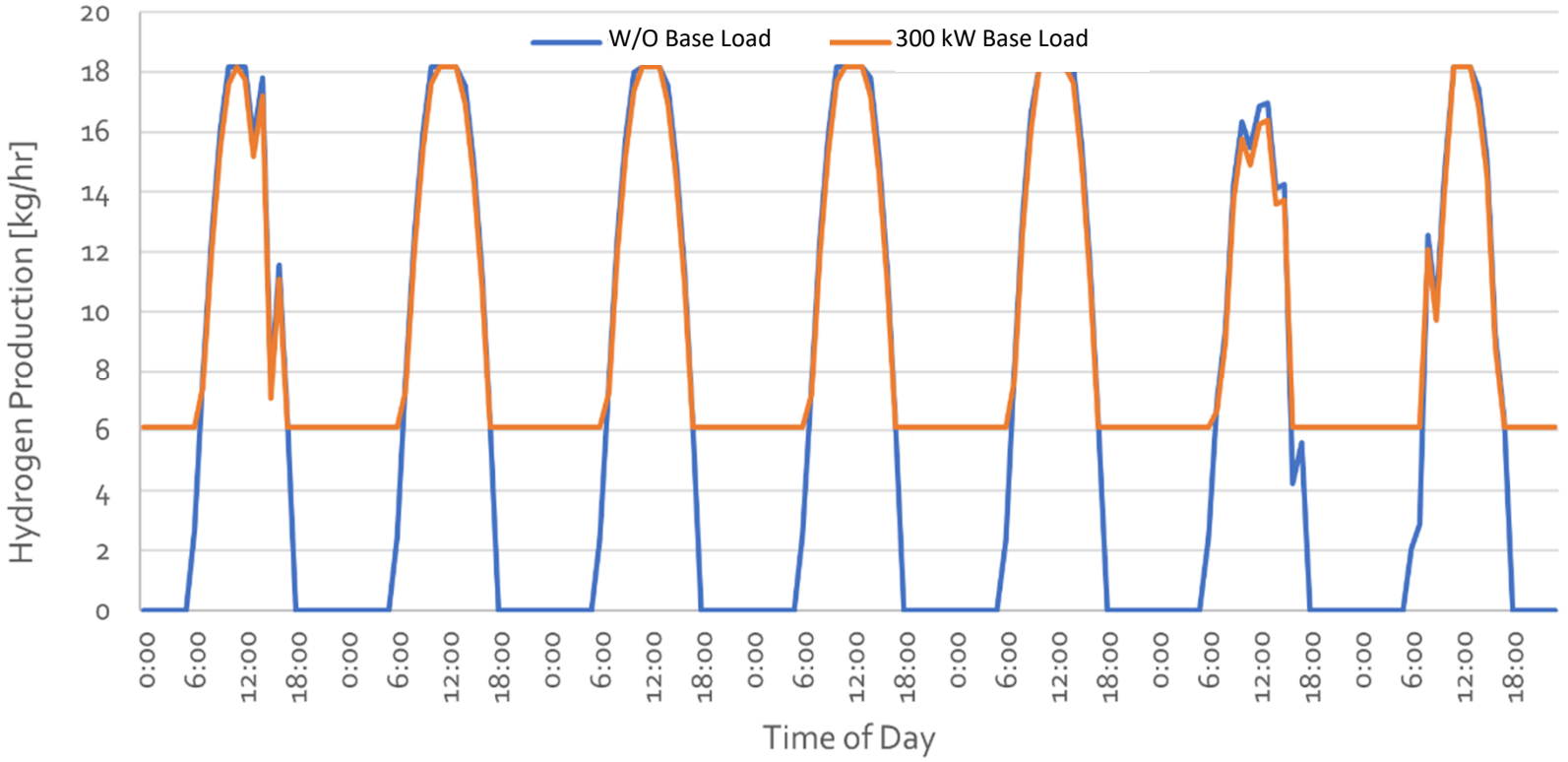
St. Cloud, MN

- Transportation
  - » Local Bus Company
  - » Bus Manufacturer
- Blend into NG Grid
- Onsite Use

Cedar Rapids, IA

- Corn/Soybean Processing
- Green Fertilizer Production
- Transportation
  - » Trucking Companies
- Onsite Use

Addressing renewable energy variability



Enhanced oxygen utilization alternatives

Membrane Aerated Biofilm Reactor

(Courtesy of Veolia)

Speece Cone

(Courtesy of ECO2)

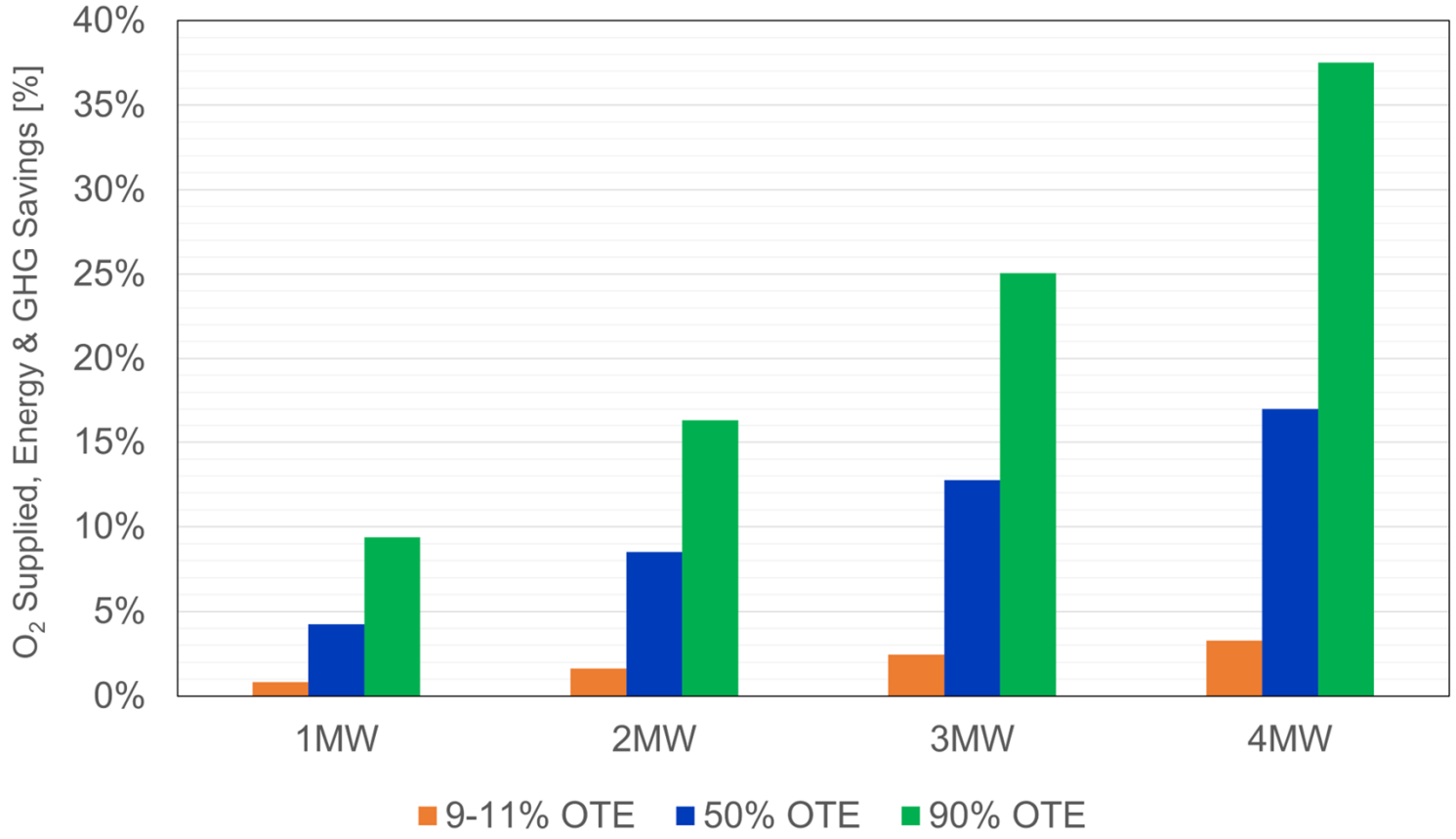
Pure Oxygen Mixer

(Courtesy of Aqua-Aerobic Systems)

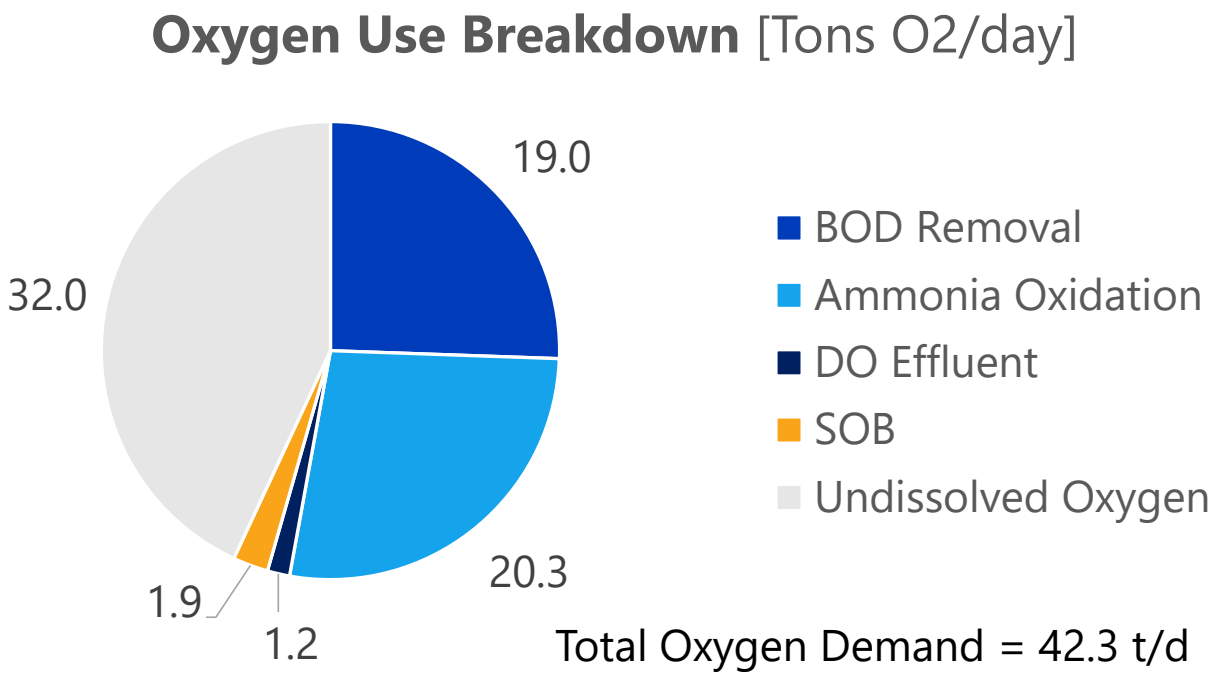
Nanobubble Technology

(Courtesy of Moleaer)

Potential benefits for St. Cloud with enhanced oxygenation system



Potential benefits for Cedar Rapids with enhanced oxygenation system



Total Oxygen Demand = 42.3 t/d

Total Oxygen Supplied = 74.3 t/d

Waste heat utilization

Electrolyzer

Process Heat for **St. Cloud**

Building Heat for **Cedar Rapids**

Financial considerations

St Cloud, MN

- Estimated Construction Costs = $10M
- Grants Awarded
  - » $1.1M – Legislative-Citizen Commission on Minnesota Resources
  - » $3.675-DOE's Decarbonization of Water Resource Recovery Facilities Program
- Status – Detailed Design Initiated

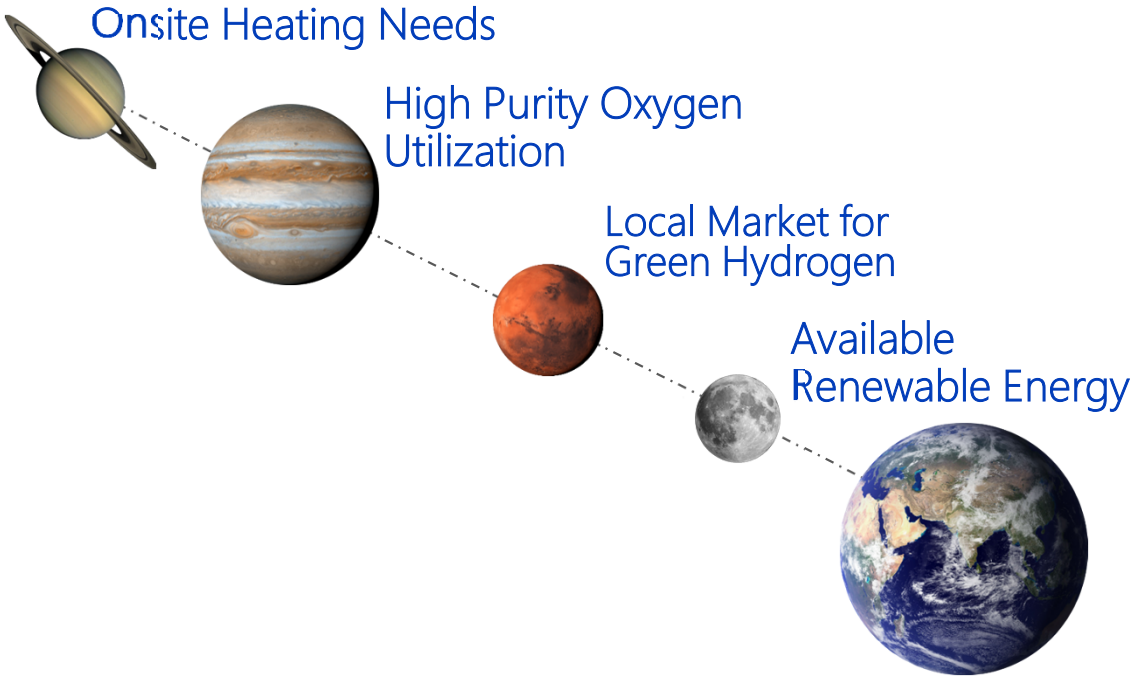
Cedar Rapids, IA

- Estimated Construction Costs = $108M
- Funding under evaluation including various grants and Inflation Reduction Act Investment Tax Credits and Production Tax Credits for Hydrogen Projects
- Status – Draft Feasibility Study Report in Review

04 Summary

Summary and conclusion

- WRRFs are suitable hosts for green hydrogen production …when the "planets" align
- WRRFs can be support decarbonization of local energy needs
- Key challenges are associated with securing 100% renewable energy sources and a market for the green hydrogen
- Significant funding and grant opportunities exist … at least for the near term



Acknowledgements

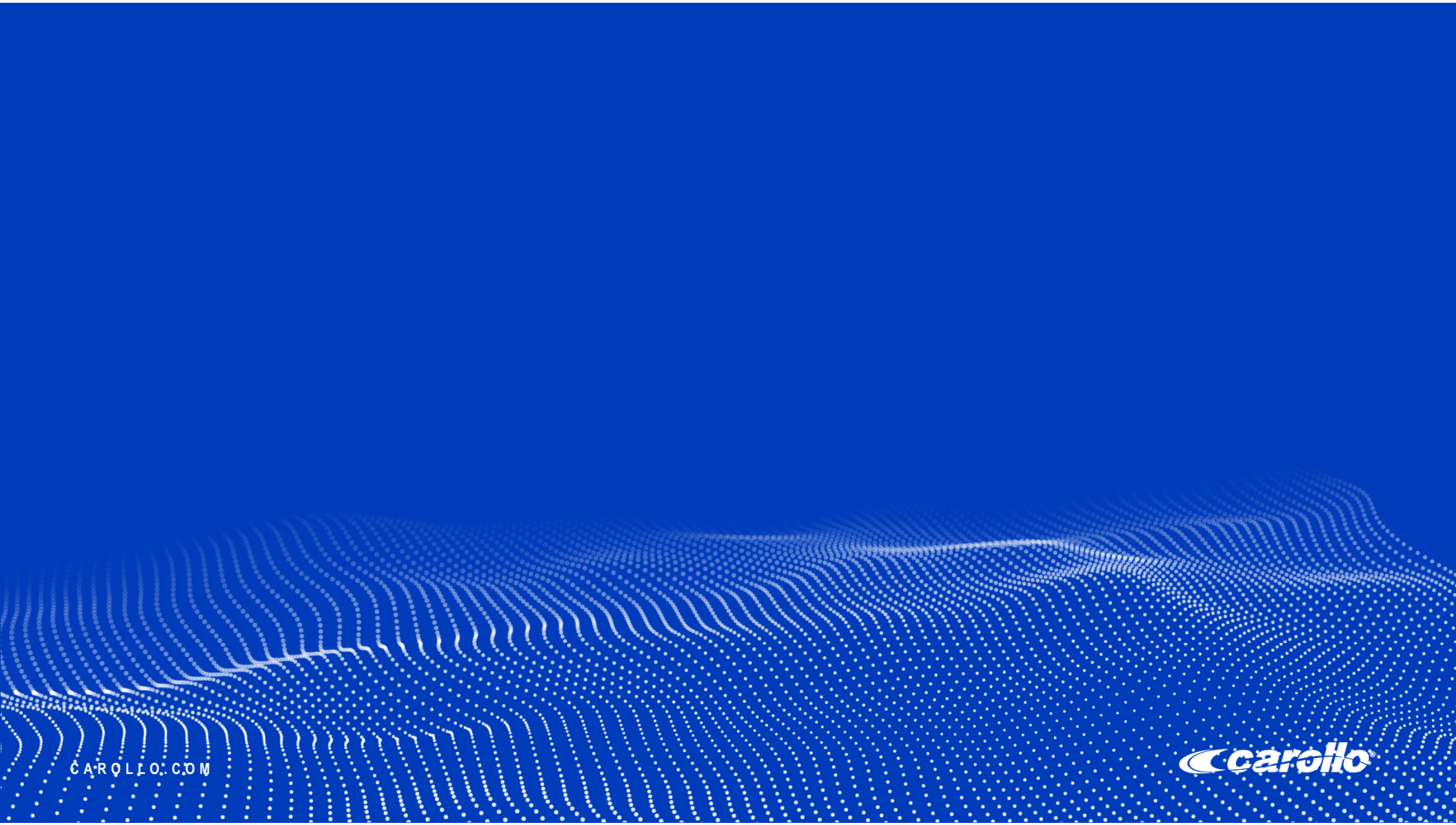
Tracy Hodel
Jacob Ethen
Emma Larson

Dale Gabel
Sam Reifsnyder
Elizabeth Charbonnet
Andrew Marsh

James Flamming

Questions

bwolohan@carollo.com


CAROLLO.COM
carollo

Hydrogen vs Methane

1. **Chemical Formula: H2 vs. CH4**

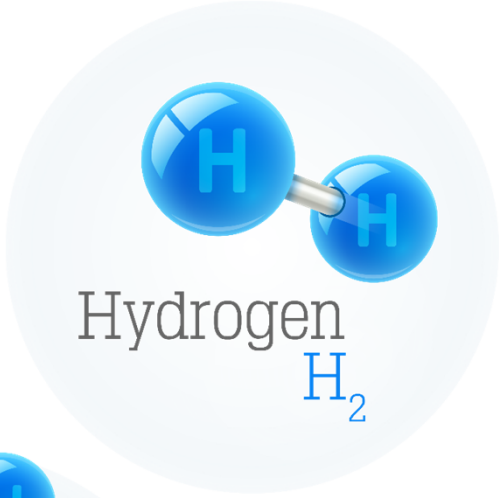
   Hydrogen combustion doesn't create carbon emissions

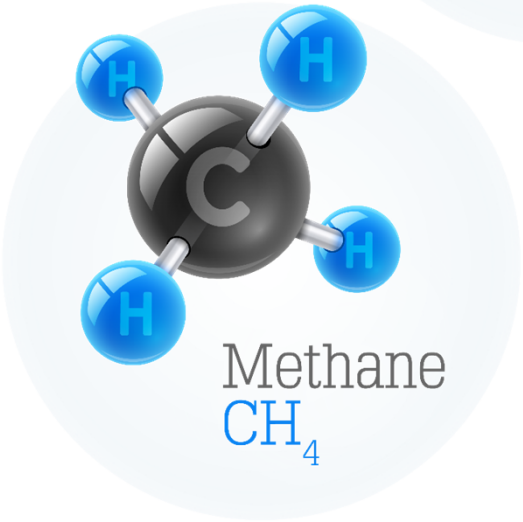
2. **Molecular Weight**

   Hydrogen is smaller and lighter and can pass through smaller cracks than methane

3. **Flammability Limits**

   Hydrogen combusts with higher and lower air concentrations





Hydrogen vs Methane (continued)

4. Flame Speed

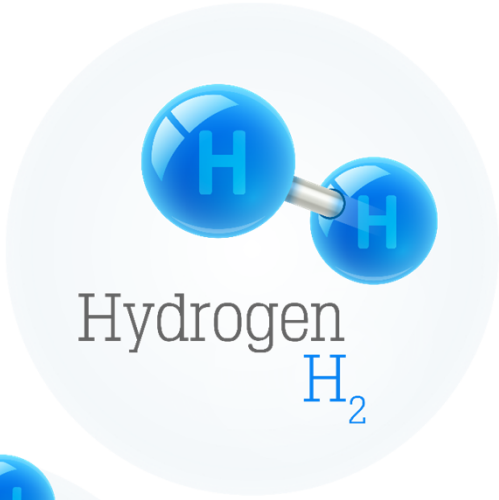
Hydrogen flame speed is 10x faster than methane

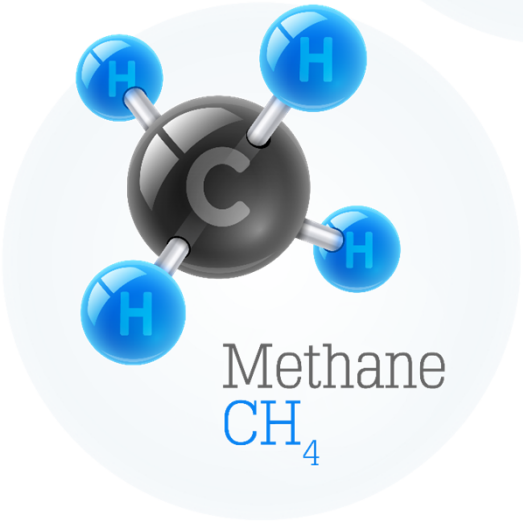
5. Adiabatic Flame Temperature

Hydrogen burns hotter that methane

6. Heating Value

Need 3x volume of hydrogen to get energy value of methane





Pure oxygen utilization

St. Cloud, MN

- Blend into existing blower header
- Enhanced aeration system for direct use of pure oxygen - future

Cedar Rapids, IA

- Replacement of aging cryogenic oxygen production system
- Enhanced aeration system for more efficient use of pure oxygen - TBD

Renewable energy sources

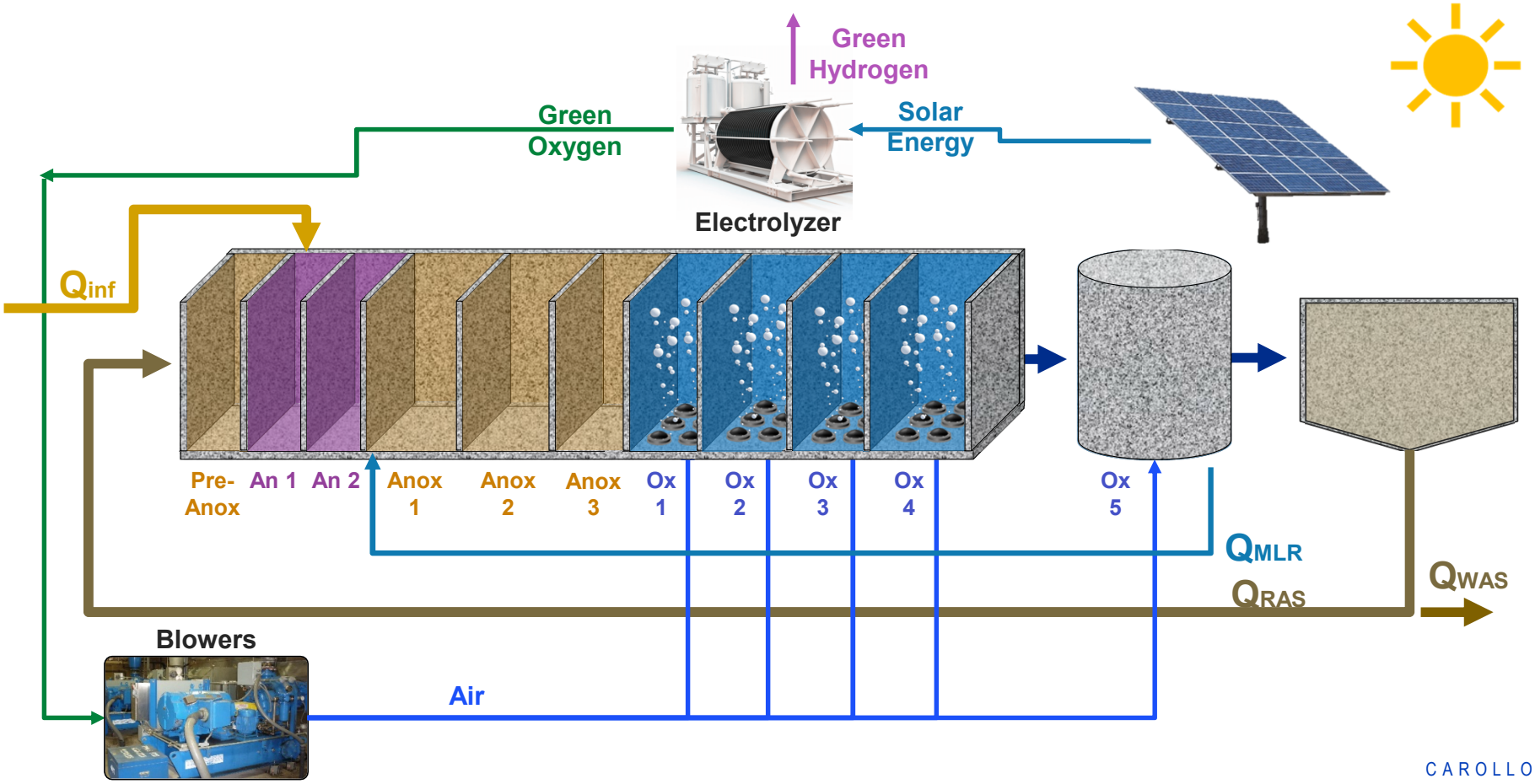
St. Cloud, MN

- Dedicated Solar Array
- Solar Garden Contract (PPA)
- Biogas

Cedar Rapids, IA

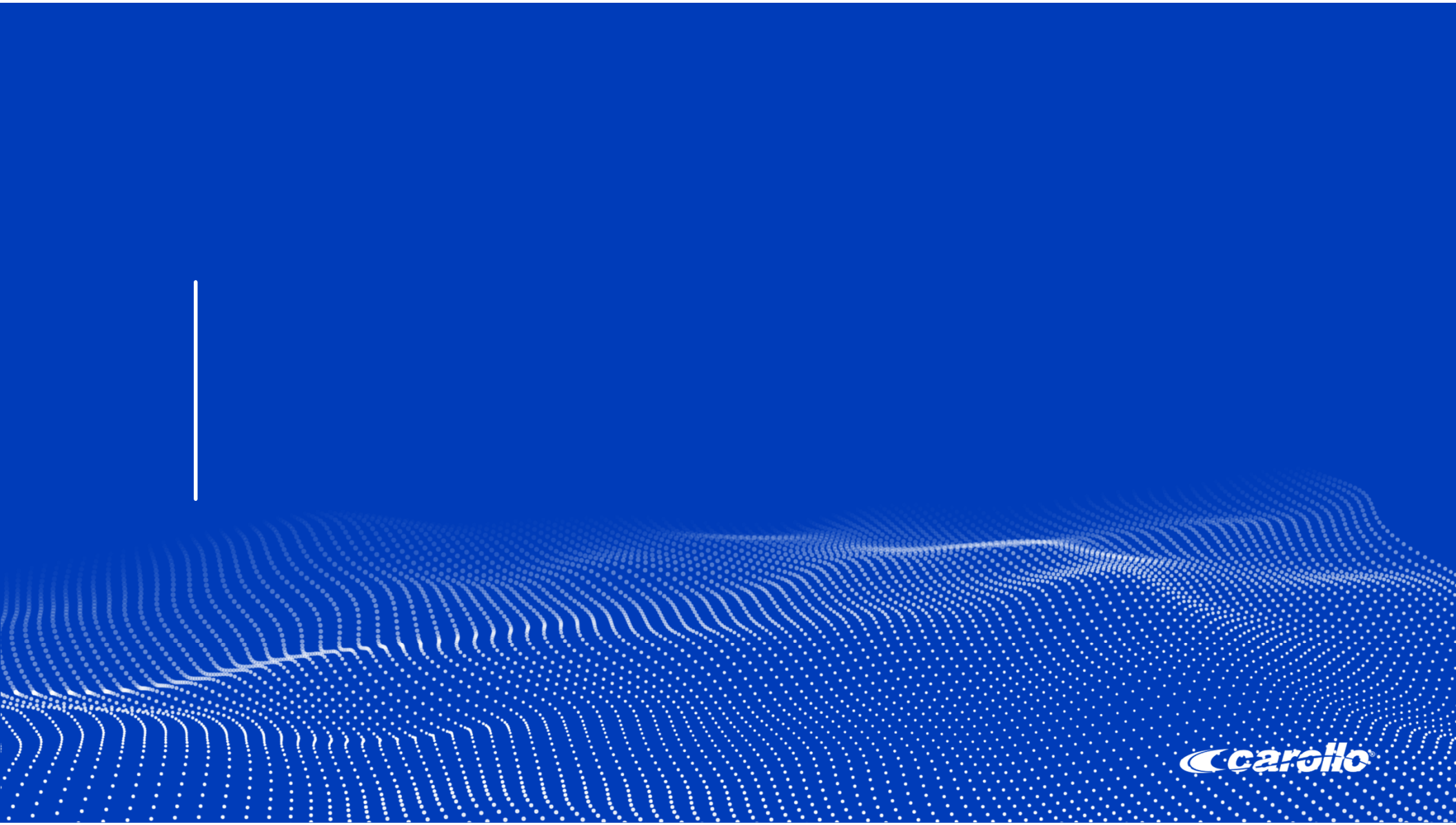
- Wind/Solar Contract (PPA)
- Biogas
- Dedicated Wind Farm/ Solar Array?

St. Cloud integration into existing system



Cedar Rapids integration into existing system

Click to edit text


carollo

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

Click to add First and Last Name

Role (optional)

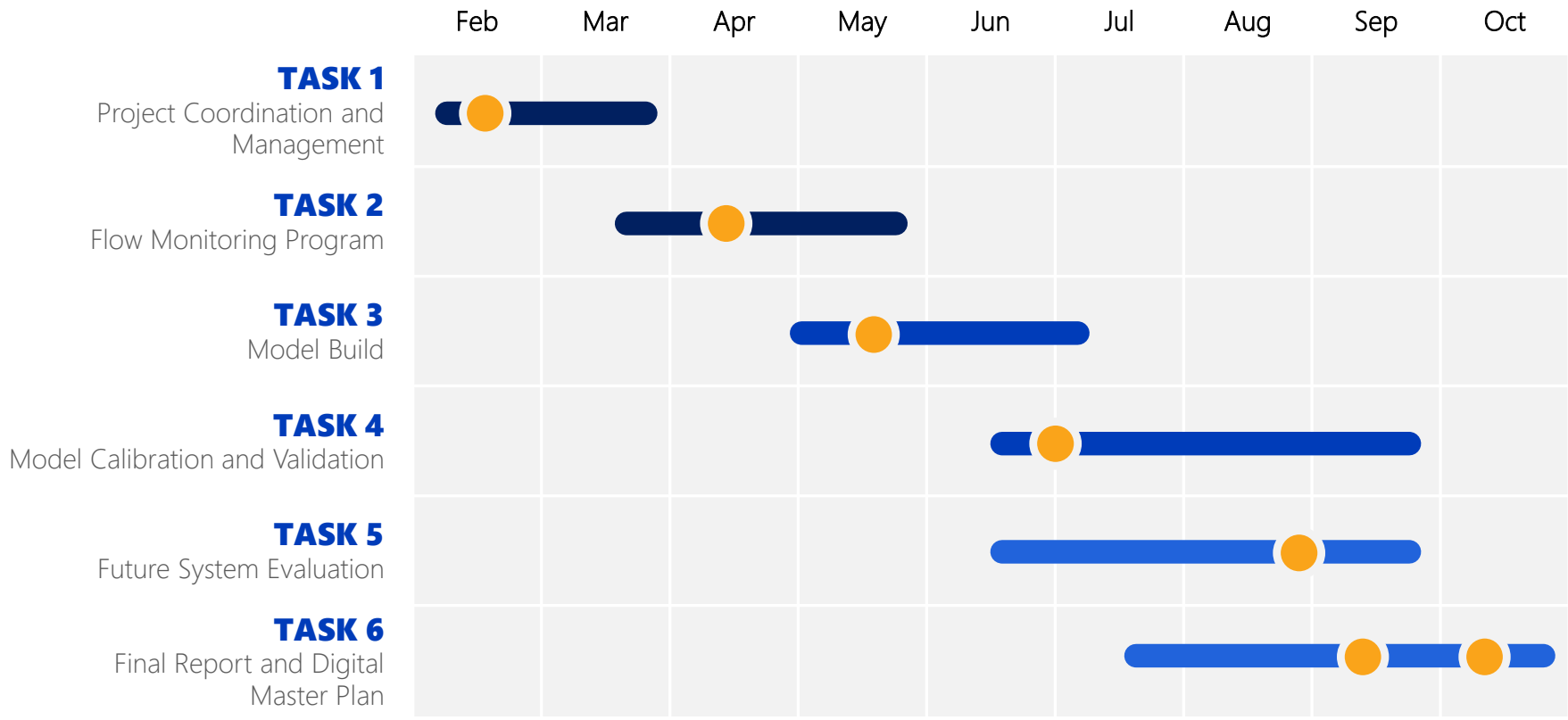
Click to add First and Last Name

Role (optional)

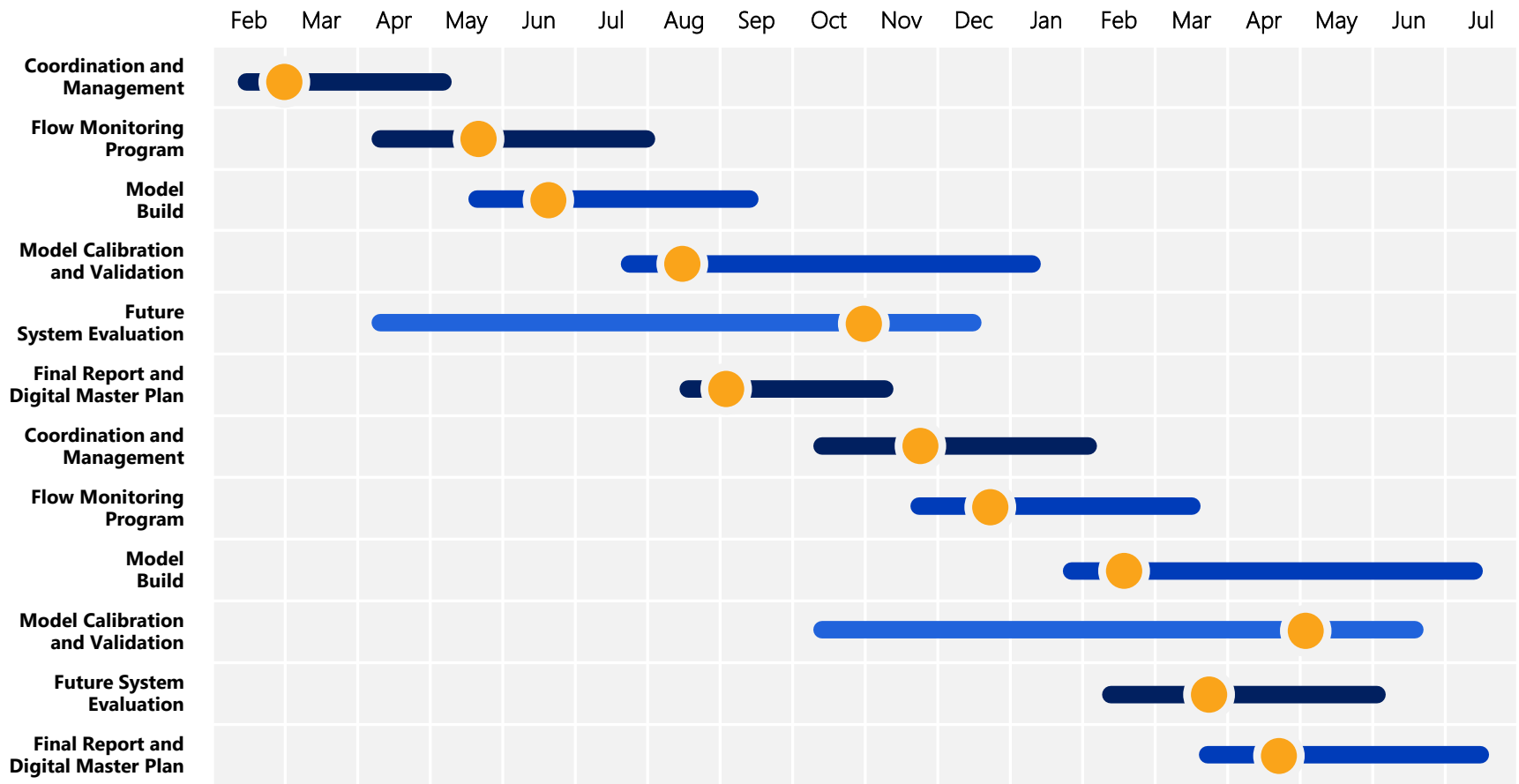
Click to add First and Last Name

Role (optional)

Sample schedule style



Sample schedule style

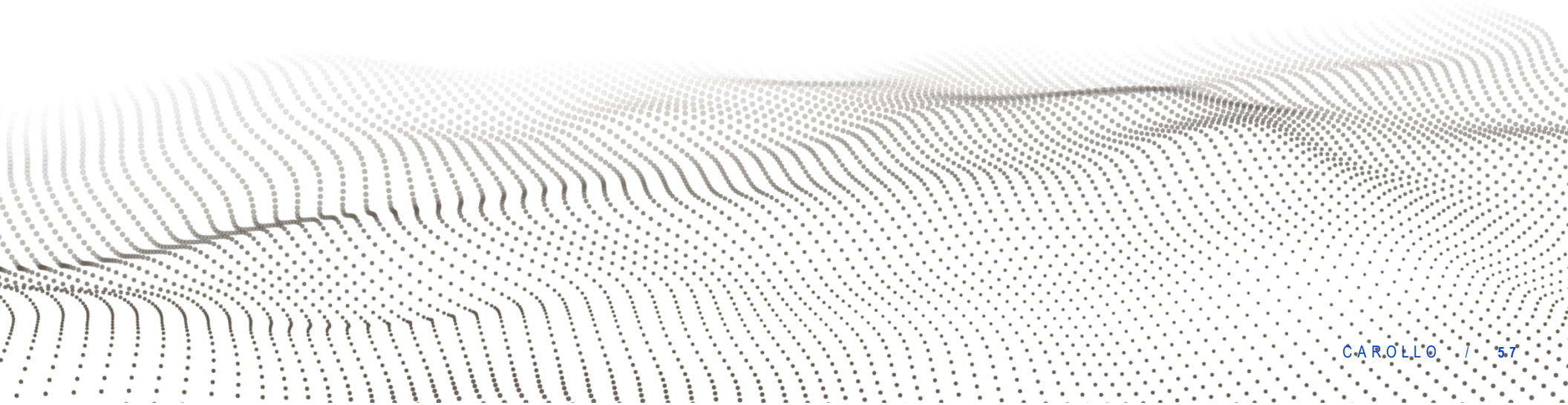


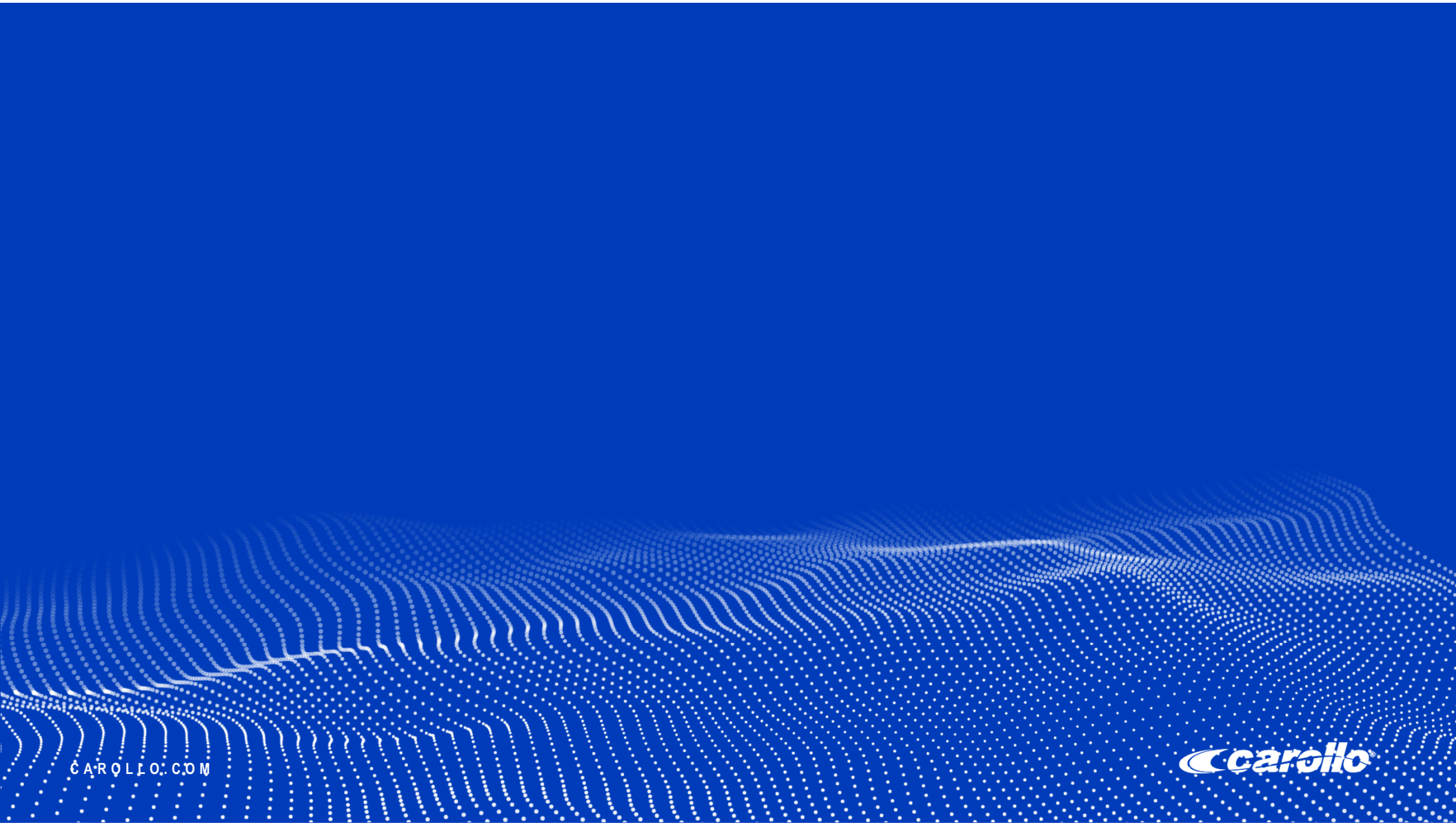
Sample table style

Header	Header	Header	Header
Pathogens	High	Medium	Pathogens
Pharmaceuticals	Low	Low	Pharmaceuticals
Concentrate	Medium	High	Concentrate
Energy	Low	Medium	Energy
Accessibility	Medium	Low	Accessibility
Pathogens	High	Medium	Pathogens

Click to add caption

Click to add caption




CAROLLO.COM
carollo

Carollo color palette