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FIT FOR THE FUTURE. READY FOR renewable gases.

Applying in line inspection technology to confirm infrastructure renewable gas readiness – Lessons learned

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OUR STORYLINE FOR TODAY

Introduction

Key Insights Around the Energy Transition

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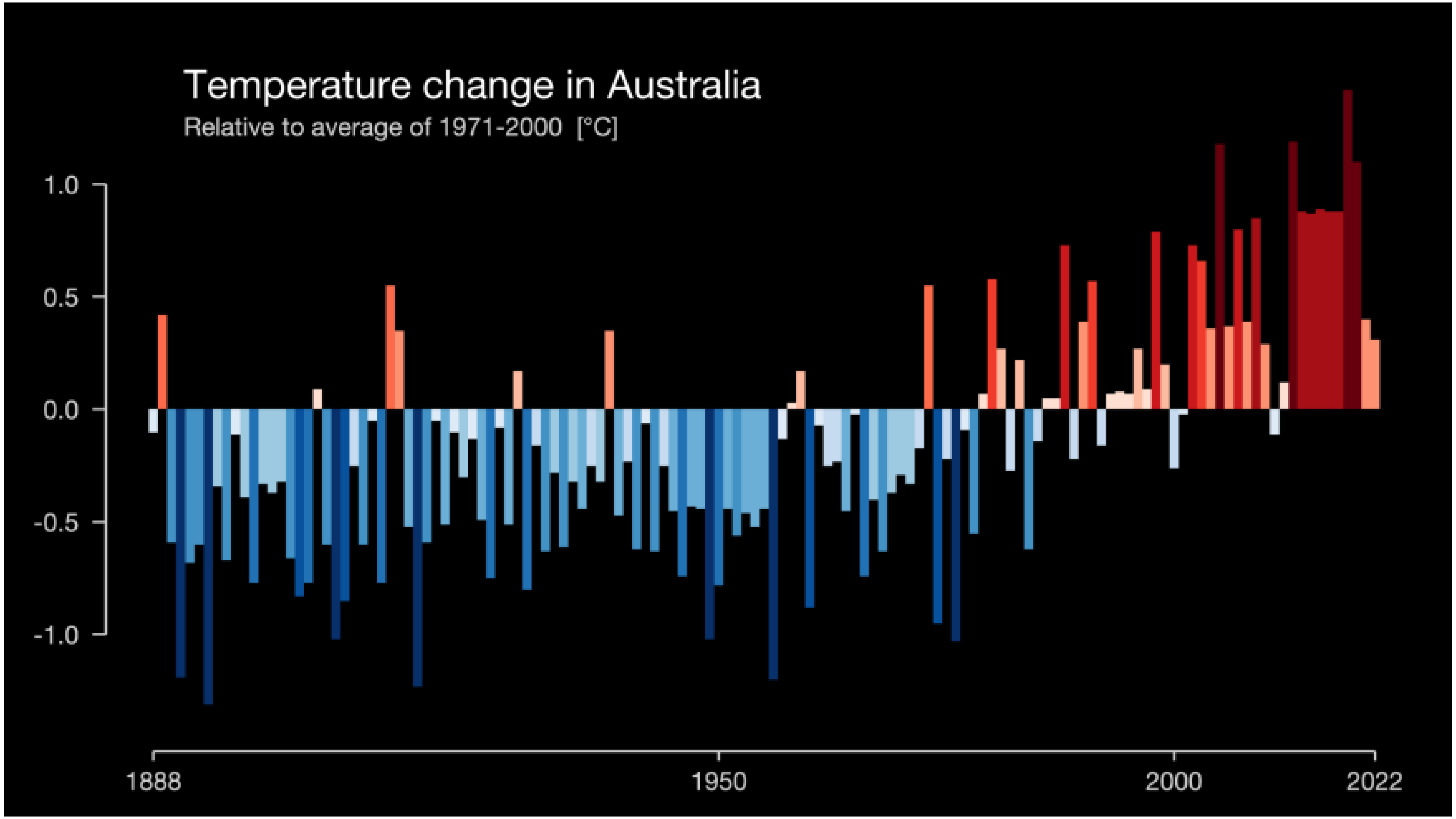
THE CLIMATE EMERGENCY IS TANGIBLE

- Global temperatures have increased by over 1.2 ºC
- Accumulated temperature data shows impact on all continents
- Emission reduction commitments have been made (Net Zero 2050)
- Rapid changes are ongoing to transform the energy industry to lower emissions

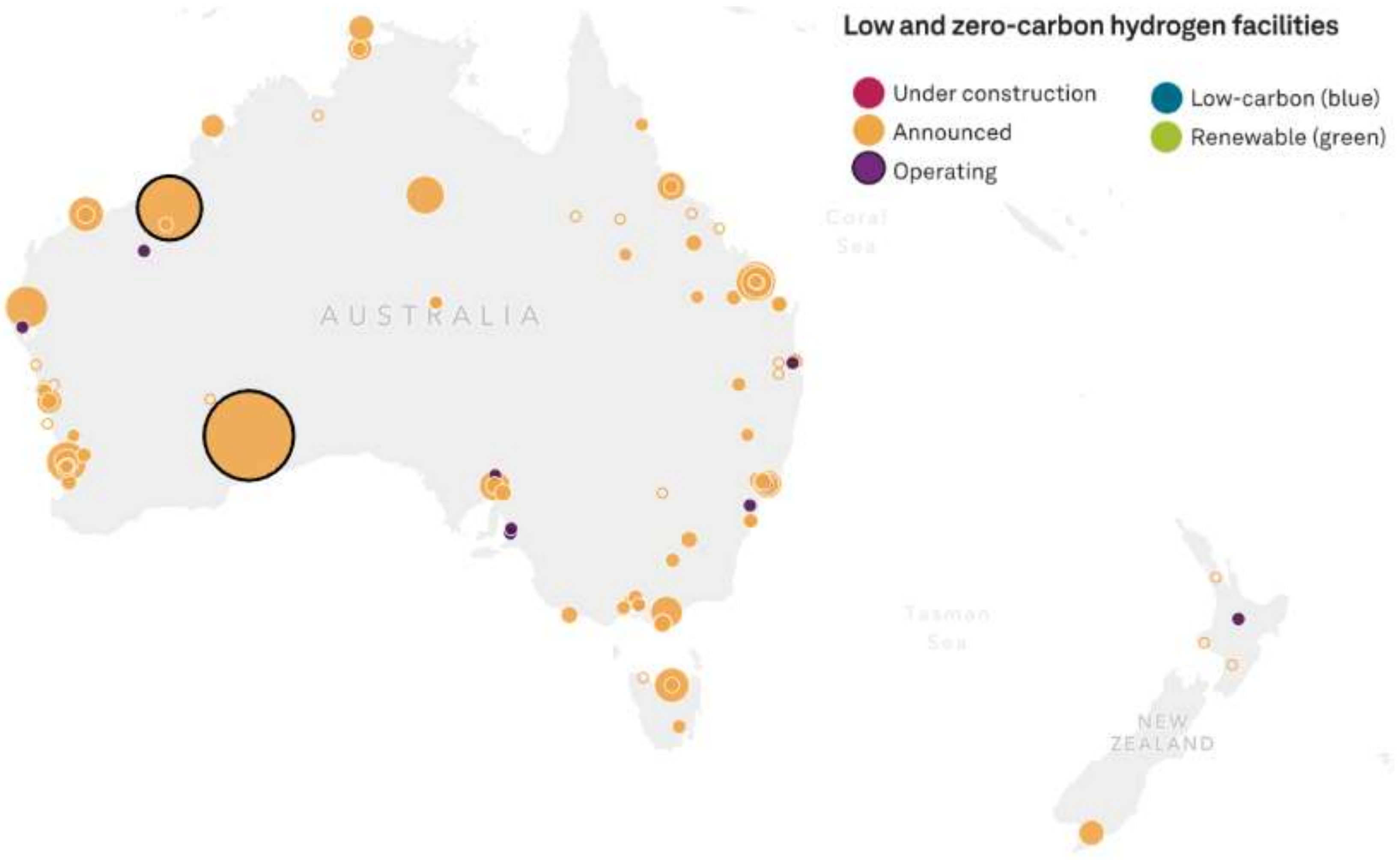


Data source: University of Reading (Ed Hawkins / Climatestripes)

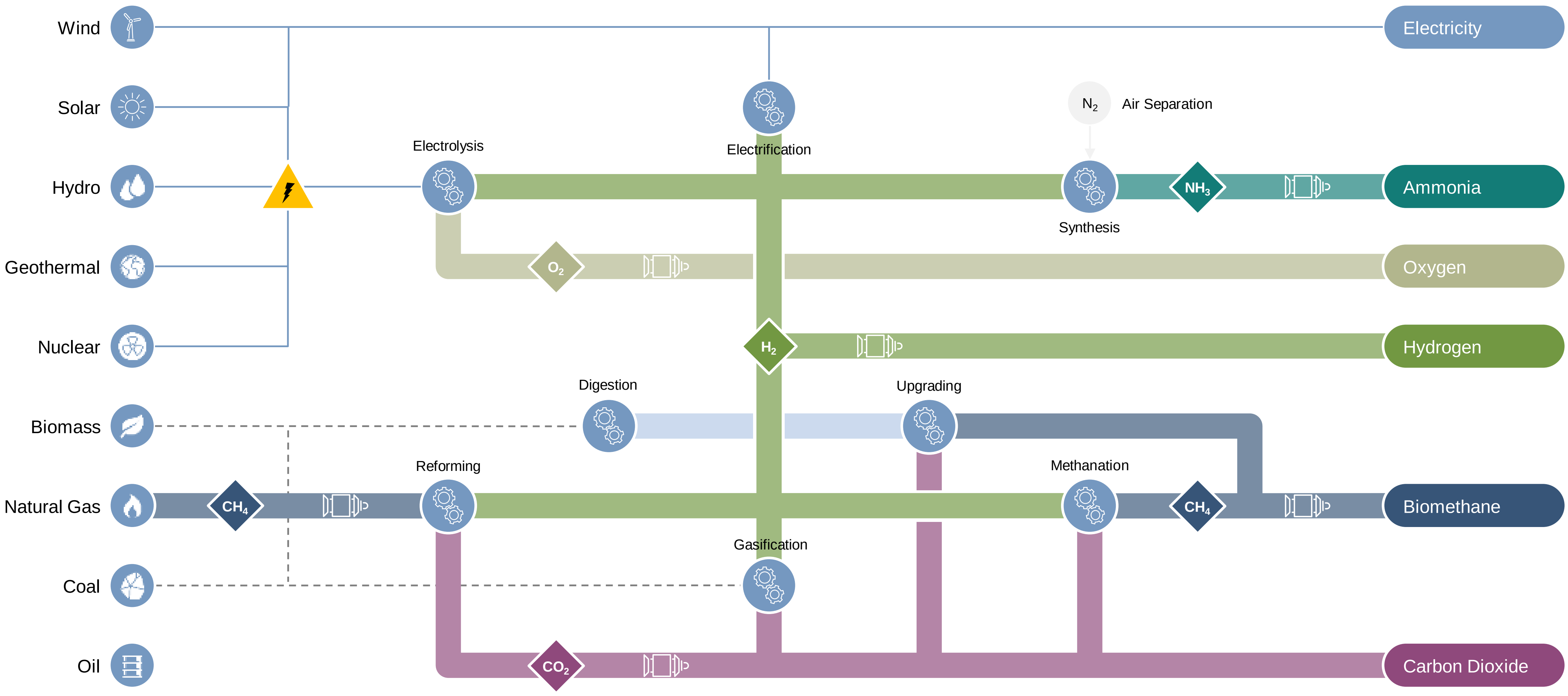
CREATION OF A DEDICATED HYDROGEN INFRASTRUCTURE

- There are over 100 hydrogen related projects under development in Australia now
- More than 15 projects have passed FID

Data source: S&P Global Commodity Insights – Atlas of Energy Transition



PIPELINES WILL PLAY A MAJOR ROLE IN A FUTURE ENERGY SYSTEM



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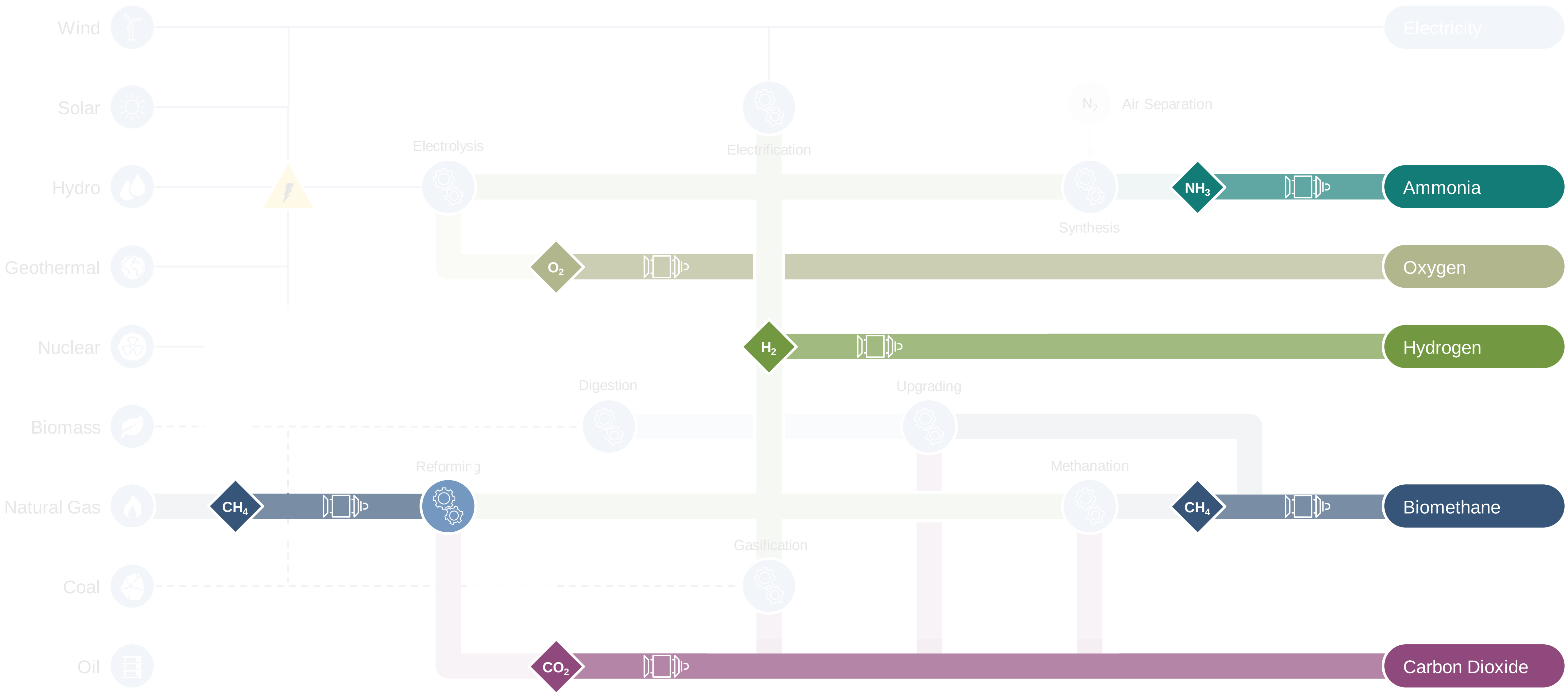
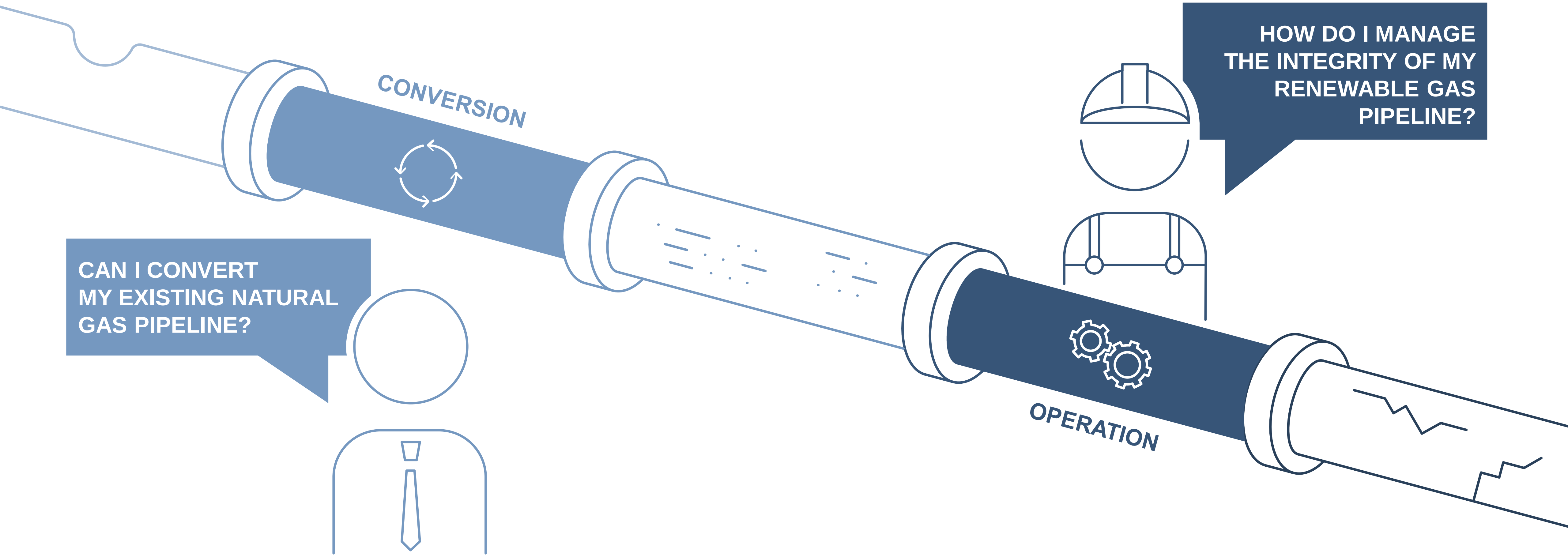


PIPELINE OPERATORS ARE NOW FACING NEW CHALLENGES



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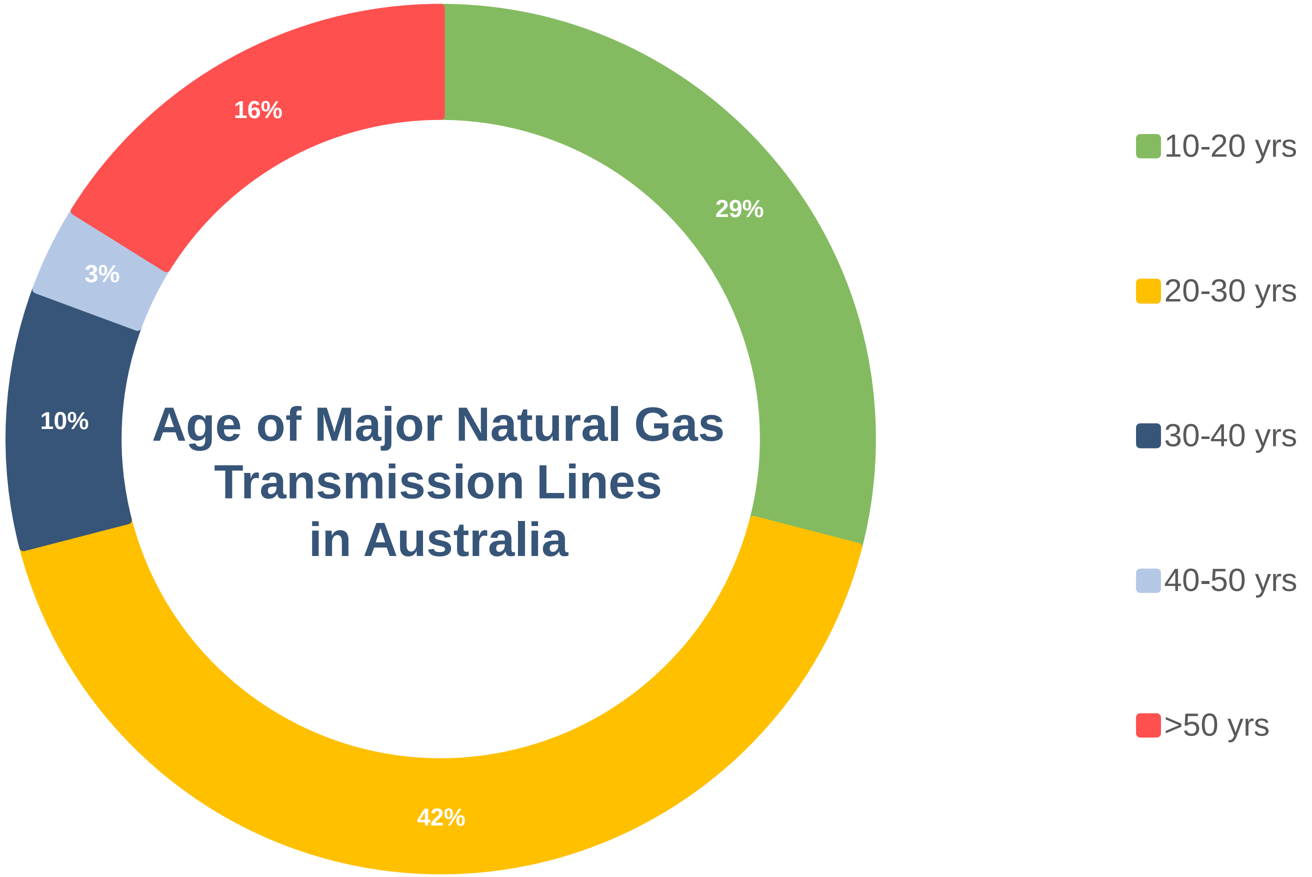
Integrity Threats

In Context of Renewable Gases

THREATS TO MANAGE IN RENEWABLE GAS PIPELINES

- Australia's pipelines are aging.
- 71% are >20 years old
- With increased age comes increased susceptibility to integrity threats



THREATS TO MANAGE IN RENEWABLE GAS PIPELINES

Cause of the Threat	Integrity Threat	Feature Type	Applicable Technology
Standard Threats for Pipelines Not Product Related	External Corrosion	Metal Loss	**MFL-A/C –** Magnetic Flux Leakage **IEC –** Internal Eddy Currant **UTWM –** Ultrasonic Wall Thickness Measurement *(Liquid Couplant Required)*
	3rd Part Damages	Dents, Gouges	**XT –** Hi Res Caliper Arm
	Geo-Hazard	Bending Strain	**XYZ –** Inertial Measurement Unit
	Manufacturing / Construction (Materials & Welding)	Crack-Like / Cracks	**EMAT –** Electromagnetic Acoustic Transducer **UT-A/C –** Ultrasonic Crack Detection *(Liquid Couplant Required)*
	External - Environmental Assisted Cracking (EAC)	Cracks	**EMAT –** Electromagnetic Acoustic Transducer **UT-A/C –** Ultrasonic Crack Detection *(Liquid Couplant Required)*
Hydrogen	Material Embrittlement	Low Fracture Toughness Under H2 Environment	**PGS** – Pipe Grade / Yield Strength Detection
	Hydrogen Cracking Damages	Cracks	**EMAT** – Electromagnetic Acoustic Transducer **UT-A/C –** Ultrasonic Crack Detection *(Liquid Couplant Required)*
	Additional Considerations	Hard-Spots, Geometry Anomalies, Bending Strain	**DMG** – Dual Magnetic Flux – Hardspot Tool
Carbon Dioxide	Ductile Fracture	Low Material Toughness	**PGS –** Pipe Grade / Yield Strength Detection
	Internal Corrosion	Metal Loss	**MFL-A/C –** Magnetic Flux Leakage **IEC –** Internal Eddy Currant **UTWM –** Ultrasonic Wall Thickness Measurement *(Liquid Couplant Required)*
	Internal SCC	Cracks	**EMAT** – Electromagnetic Acoustic Transducer **UT-A/C –** Ultrasonic Crack Detection *(Liquid Couplant Required)*
Ammonia	Internal SCC	Cracks	**EMAT** – Electromagnetic Acoustic Transducer **UT-A/C –** Ultrasonic Crack Detection *(Liquid Couplant Required)*
	Internal Corrosion	Metal Loss	**MFL-A/C –** Magnetic Flux Leakage **IEC –** Internal Eddy Currant **UTWM –** Ultrasonic Wall Thickness Measurement *(Liquid Couplant Required)*

Integrity Assessment Methods for repurposing of existing pipelines

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INTEGRITY ASSESSMENT METHODS FOR REPURPOSING OF EXISTING PIPELINES

In Line Inspection	• ILI is a non-destructive inspection technique that can be used for integrity assessment of pipelines. The type of ILI survey performed is dependent upon the type of integrity threat that is being assessed.
Pressure Testing	• Pressure testing is a (potentially) destructive testing technique to detect/eliminate (by failing) the largest defect in the pipeline at the time of the testing that can fail due to internal pressure (i.e. pressure-dependent defect).
Direct Assessment	• Direct Assessment (DA) is a non-destructive assessment technique for classifying pipeline regions with common characteristics (i.e., Pre-Assessment) that may be experiencing the selected integrity threat (e.g., external corrosion, internal corrosion, or stress corrosion cracking).
Alternative Methods	• Alternative methods such as inferred condition technologies and data analytics may be used when operational (e.g., pipeline system configuration), technological (e.g., small diameters) and environmental (e.g., water availability and disposal) conditions do not permit the other three (3) main types of pipeline integrity assessment methods

Inspection technologies and necessary changes for renewable gases

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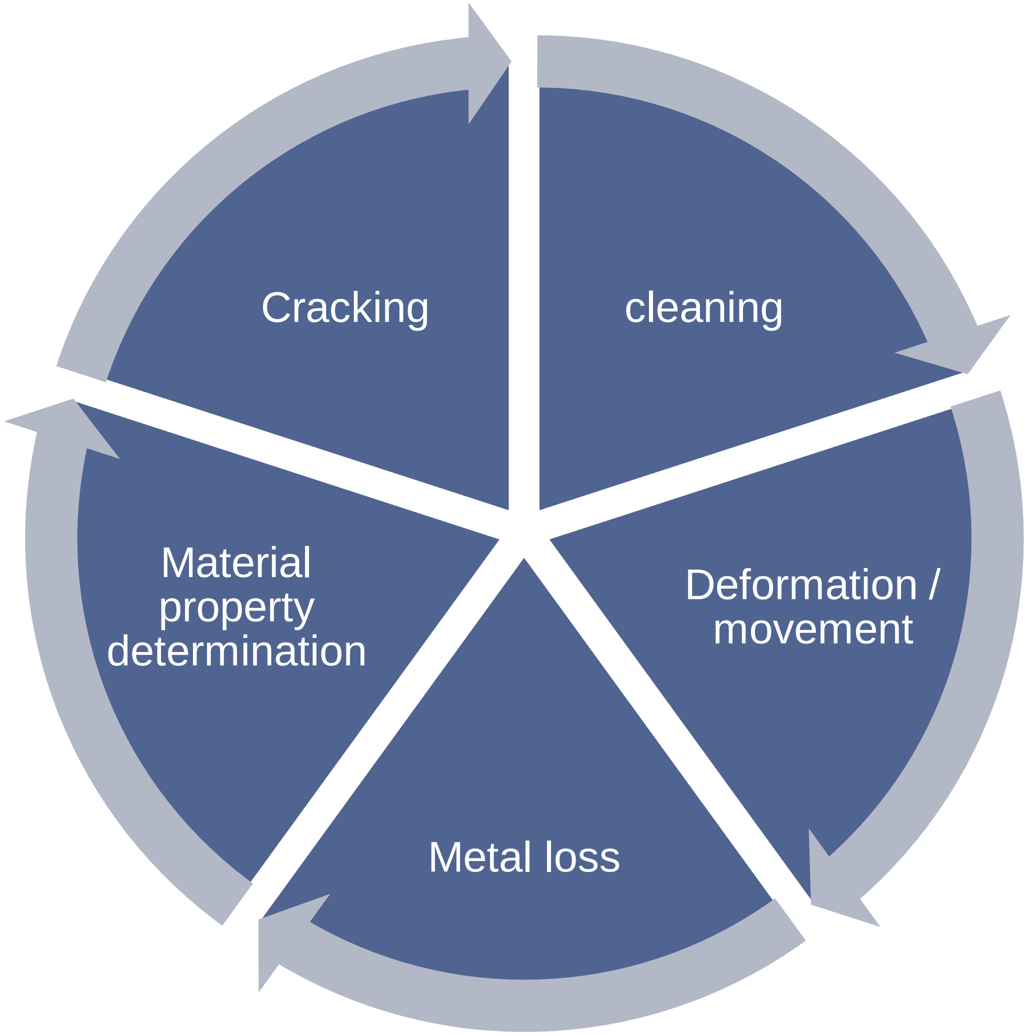
INSPECTION TECHNOLOGIES AND NECESSARY CHANGES FOR RENEWABLE GASES

- Existing technologies can address the threats expected in renewable gas pipelines
- Specific tool modifications mandatory
- In Line Inspections in H^2, CO^2 , and NH_3 have already been completed successfully
- Solutions for larger diameters and longer distances can be made available upon request
- Some operational challenges exist (e.g. high flow velocity in H^2) but can be overcome



INSPECTION TECHNOLOGIES FOR RENEWABLE GAS PIPELINES

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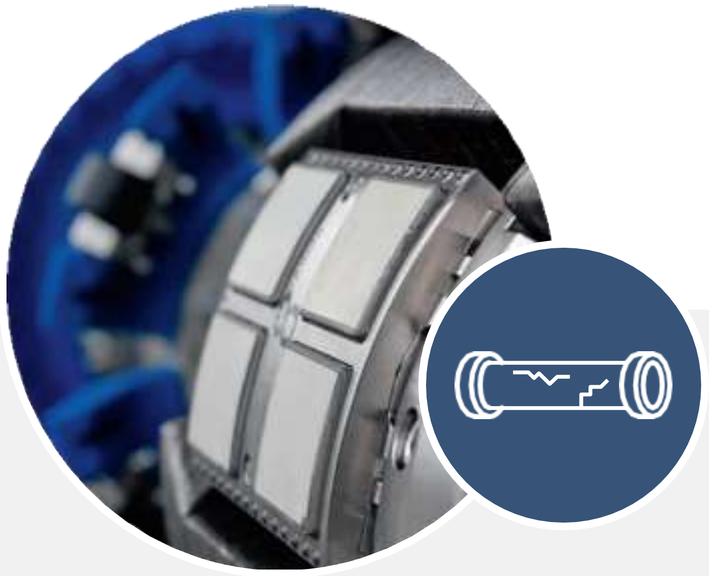
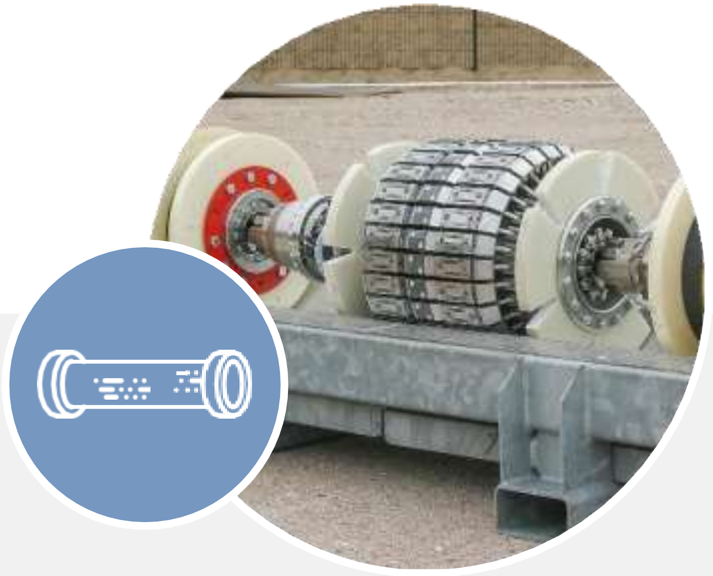


Crack Detection

Finding the cracks that matter.

- Applies the latest generation of crack detection tools for detection of axial and circumferential cracking.
- Provides reliable detection and accurate sizing using liquid coupled ultrasonic or dry coupled electromagnetic acoustic technologies.
- Process driven service - adjusted to the specific requirements of each pipeline and to the needs of the individual operator.



Material Property Determination

Take a smart look into your pipe wall.

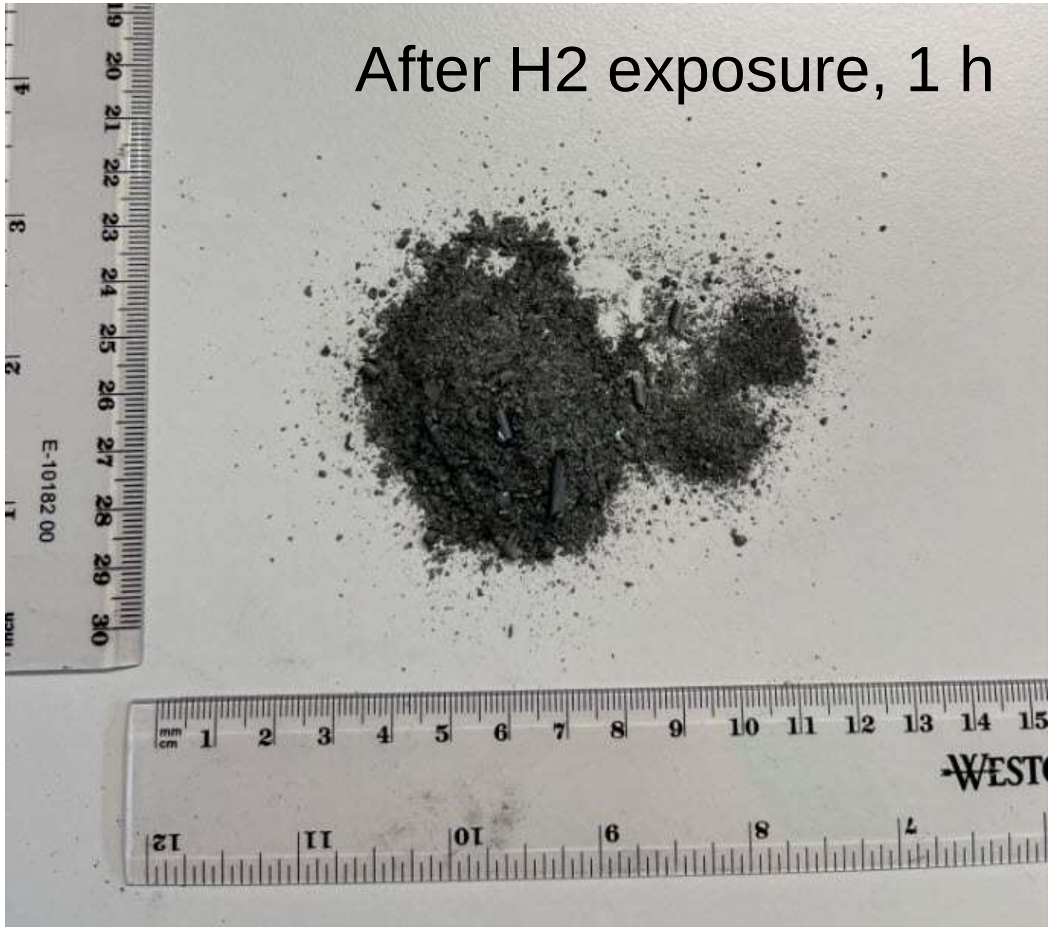
- In-line inspection service suite addresses pipe and material properties, thus putting and end to incomplete pipeline construction records.
- Material strength categorization services provide measurement of yield strength and
accurate determination of pipe grade for each joint within the examined pipeline section.
- Dual magnetization service provides a solution for inspecting pipelines with regard to local variations of the pipe wall’s metallurgical hardness, known as hard spots.

NECESSARY CHANGES FOR RENEWABLE GASES
MATERIAL SELECTION FOR ILI TOOLS

Sealants	**Cable jackets**	**Spacer**
Austenitic (Stainless) Steel	**Magnets**	**Carbon Steel with protective coating**
Rubber	**Ceramics**	**Polyurethane**

INSPECTION TECHNOLOGIES FOR RENEWABLE GAS

HYDROGEN IMPACTS ON RARE EARTH MAGNETS

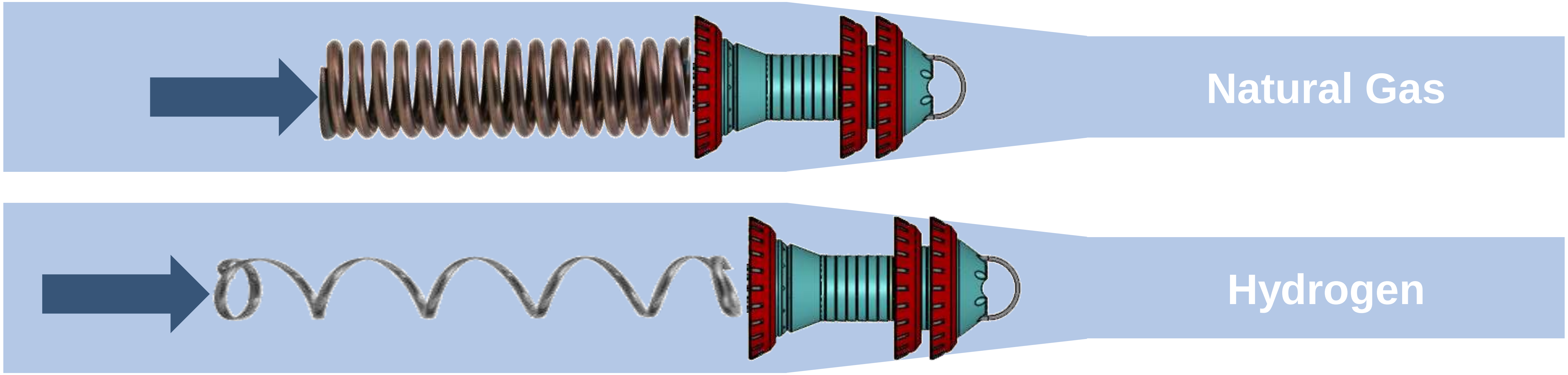


INSPECTION TECHNOLOGIES FOR RENEWABLE GAS

LOW HYDROGEN DENSITY

H^2 is considered the more challenging of the renewable gases for In Line Inspection

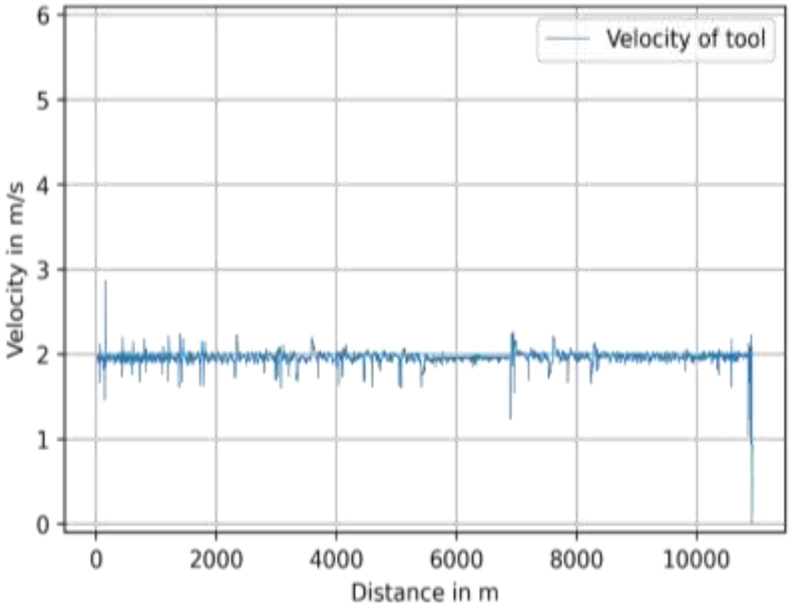
- Hydrogen has a density 1/10th that of Natural Gas in a gaseous state
- Higher flow rates expected for H^2 transportation compared to NG
- It is expected that the lower density leads to more dynamic tool run behavior with more tool stops and higher maximum tool velocity including higher speed excursions
- To overcome this challenge, active speed control devices and other speed control options will be required to control tool behavior



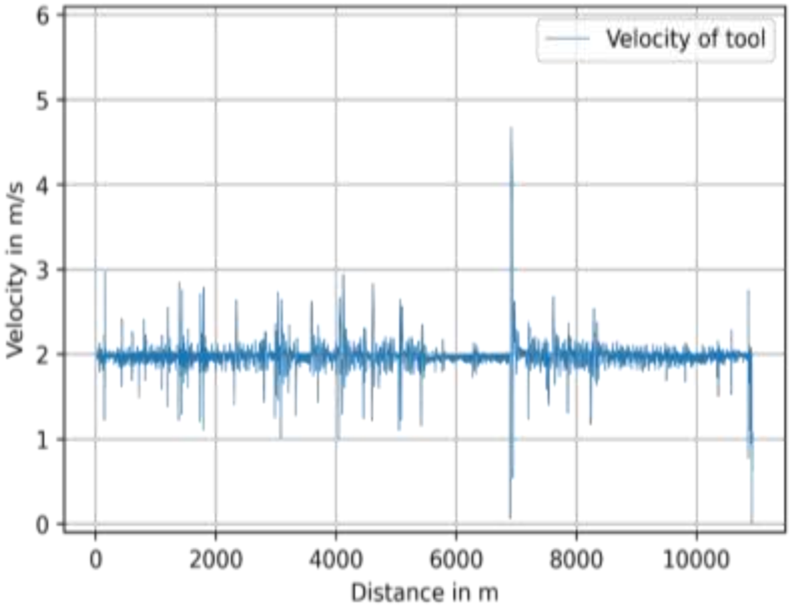
NECESSARY CHANGES FOR RENEWABLE GASES
TOOL DYNAMICS IN HYDROGEN

- Lower density and higher flow rates present an additional challenge for inspection in Hydrogen
- Additional measures (speed control units, eddy current breaks, cup setups etc.) necessary to improve run behavior in H^2

Natural Gas



Hydrogen



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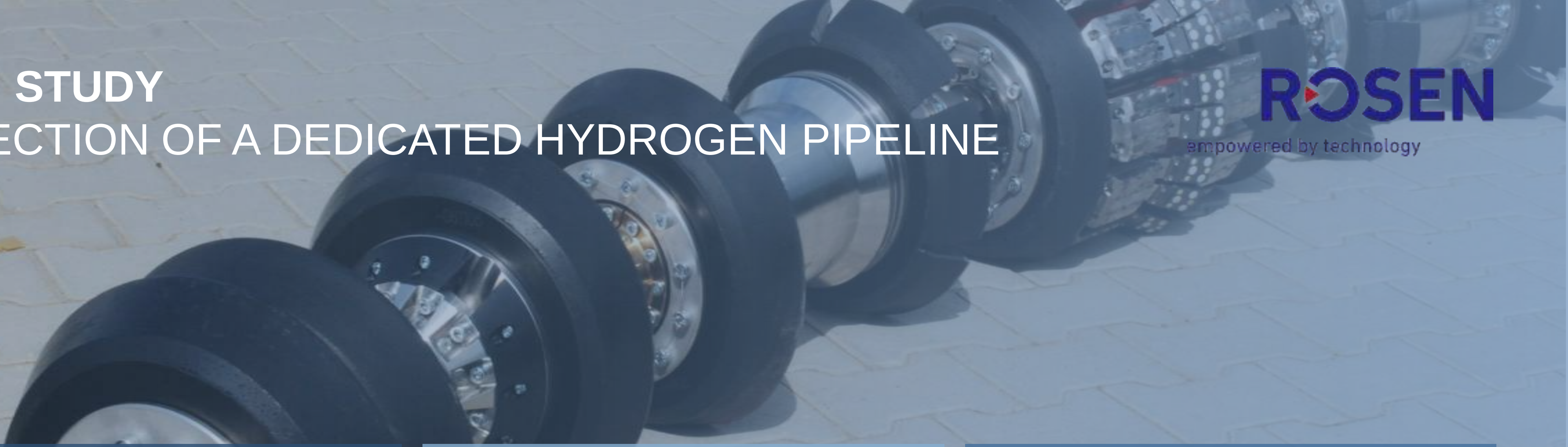
Case Studies

CASE STUDY
INSPECTION OF A DEDICATED HYDROGEN PIPELINE



The Challenge

- 19 km pipeline segment
- 10 inches in diameter and installed in 1996
- Was set up for the transportation of hydrogen.
- The only way to inspect hydrogen pipelines was by utilizing water as a propellant. This process comes at a high cost and can be quite time consuming.
- In 2015, the operator approached ROSEN for a cost-effective method to safely inspect the line segment with a combination of geometry and magnetic flux leakage technologies.

Our Solution

- To perform a successful inspection (2017) and re-inspection (2019) of the line segment, the tool setup was adapted due to the challenging environment of hydrogen.
- Inspection tools are set up in compliance with the European Union’s ATEX directives.
- The tools were set up with non-standard cups, differing in shore – meaning hardness.
- Due to hydrogen specific operating parameters of pressure and flow rates, various bypass holes and notches were applied to the tool design.
- Protective measures for the magnet circuits were taken.

The Results

- The resulting data from the combination tool showed 100 % sensor coverage and magnetization levels were within the predicted ranges.
- While the tool did experience a few spikes in velocity when traversing installation areas, the overall data quality was acceptable for evaluation.
- The use of customized hydrogen inspection tools saved the operator massive costs by not having to shut down the pipeline.
- The pipeline operator was able to make smarter decisions regarding the integrity of the hydrogen line segment, ensuring reliable hydrogen transport operations.

CASE STUDY
INSPECTION OF A DEDICATED CO2 PIPELINE

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The Challenge

- 116 km pipeline segment
- 24 inches in diameter
- Dense phase CO_2 pipeline at 131 bar
- Geometry and Magnetic Flux Leakage inspections
- At 16° Celsius launching temperature
- Low flow rate

Our Solution

- ILI tool preparation for long run & long exposure time (180 hours)
- Special tool setup chosen with special sealants and rubber setup
- Full refurbishment of the tool planned after the run

The Results

- Data have been recorded successfully
- 100 % sensor coverage and magnetization levels were within the predicted ranges
- Cups and discs show normal wear
- No sign of significant affect on the tool due to the long run duration and exposure time
- A few hours after tool receipt plastic and rubber parts started to sell and bubbles appeared as it was expected

CASE STUDY
INSPECTION OF A DEDICATED AMMONIA

The Challenge

- 4.5 km pipeline in Australia
- 06 inches (168.3 mm) in Diameter constructed in 2000
- Ammonia at 1 bar
- Cleaning and Magnetic Flux Leakage Inspections

Our Solution

- ILI tool preparation for Ammonia exposure
- Special tool setup chosen with special polyurethane blend for ammonia, special cable jackets, EPDM elastomers for o-rings, and titanium for certain components
- Disposal of all polyurethane and elastomer-based components after the inspection. Full breakdown and refurbishment of the tool planned after the run

The Results

- Data recorded successfully
- 100 % sensor coverage and magnetization levels were within the predicted ranges
- Cups and discs show wear as expected in Ammonia
- Ammonia impacts visible, but mitigation measures and special materials worked as designed
- Exposure time in ammonia is still a key variable when considering In Line Inspections in ammonia

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Conclusions

CONCLUSIONS

Key Takeaways

- ILI solutions for renewable gas pipelines already exist
- No major ILI technology developments are required to address the integrity threats to renewable gas pipelines
- Understanding the specific threats for renewable gases is key to ensuring correct selection of ILI technologies
- Technologies capable of detecting crack-like anomalies and material properties will be important in managing the integrity of renewable gas assets
- ILI technologies for determining pipe grade / yield strength can reduce the onerous requirements of 1 per mile sampling requirements as per ASME B31.12
- Renewable gases impact common ILI components more aggressively. Careful selection of ILI component materials for specific gases is critical
- Operational conditions in renewable gas pipelines are more challenging (e.g. H^2 flow velocity), but these challenges can be overcome

AN OVERVIEW OF OUR HYDROGEN ACTIVITIES

Thank You for Joining This Presentation