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ICHS
International Conference on Hydrogen Safety

INTERNATIONAL CONFERENCE ON HYDROGEN SAFETY 2021

Crack Management in Hydrogen Pipelines

In cooperation with

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presented by

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Principal Engineer

GRADUAL CREATION OF A DEDICATED HYDROGEN INFRASTRUCTURE

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Connecting industrial clusters to an emerging infrastructure in 2030

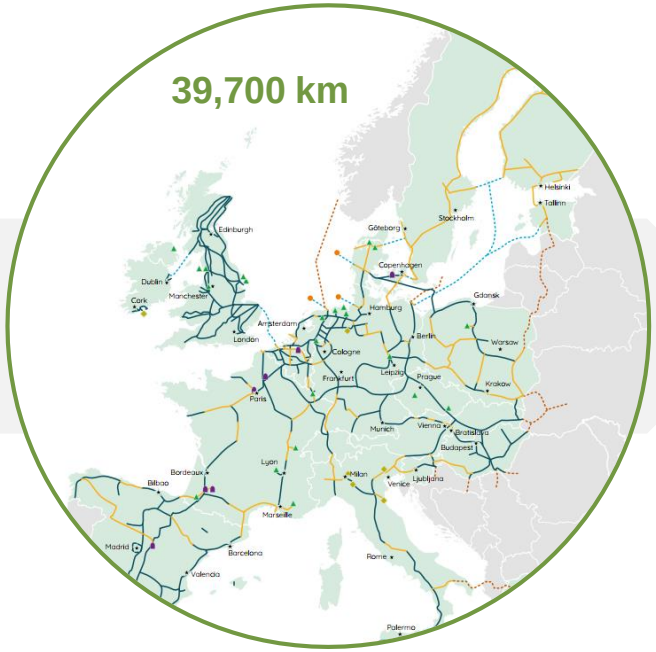
Dedicated European Hydrogen Backbone can develop with a total length of approximately 11,600 km, consisting mainly of retrofitted existing natural gas pipelines.

Regional backbones are expected to form in and around first-mover hydrogen valleys.

Growing network by 2035 covers more countries and enables import

The European Hydrogen Backbone will continue to grow, covering more regions and developing new interconnections across member states.

Dedicated hydrogen storage facilities such as salt caverns, depleted fields and aquifers become increasingly important to balance fluctuations in supply and demand.

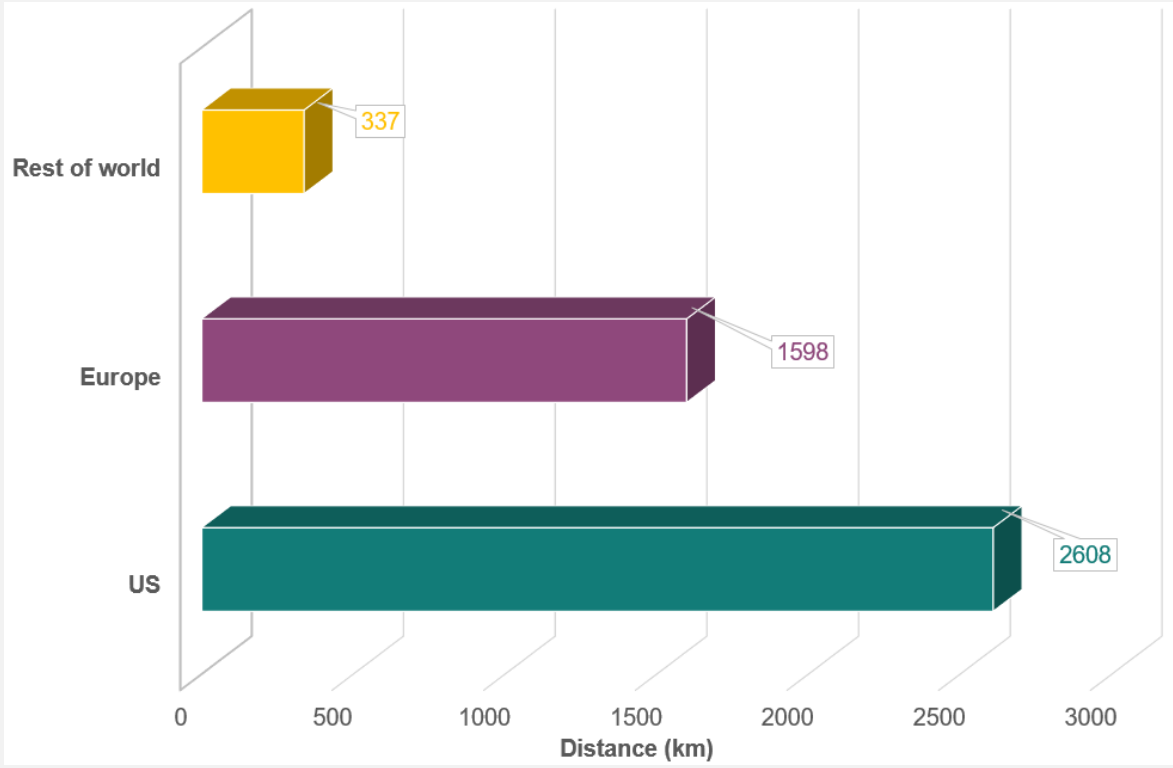


Mature infrastructure stretching towards all directions by 2040

The proposed backbone can have a total length of 39,700 km, consisting of approximately 69% retrofitted existing infrastructure and 31% of new hydrogen pipelines.

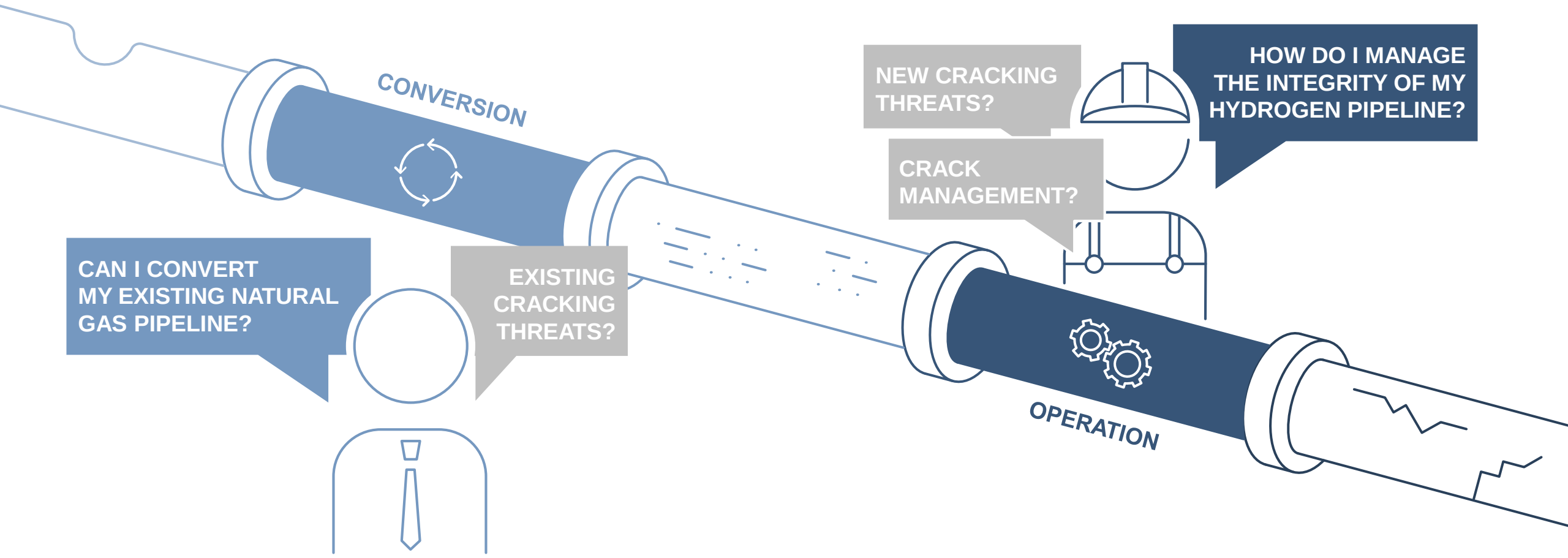
Total estimate investment is expected to be between 43 and 81 billion euros

HYDROGEN PIPELINES?



- ASME B31.12 / EIGA / AIGA
- Low grade
- Relatively small diameter
- Low utilisation

PIPELINE OPERATORS ARE NOW FACING NEW CHALLENGES



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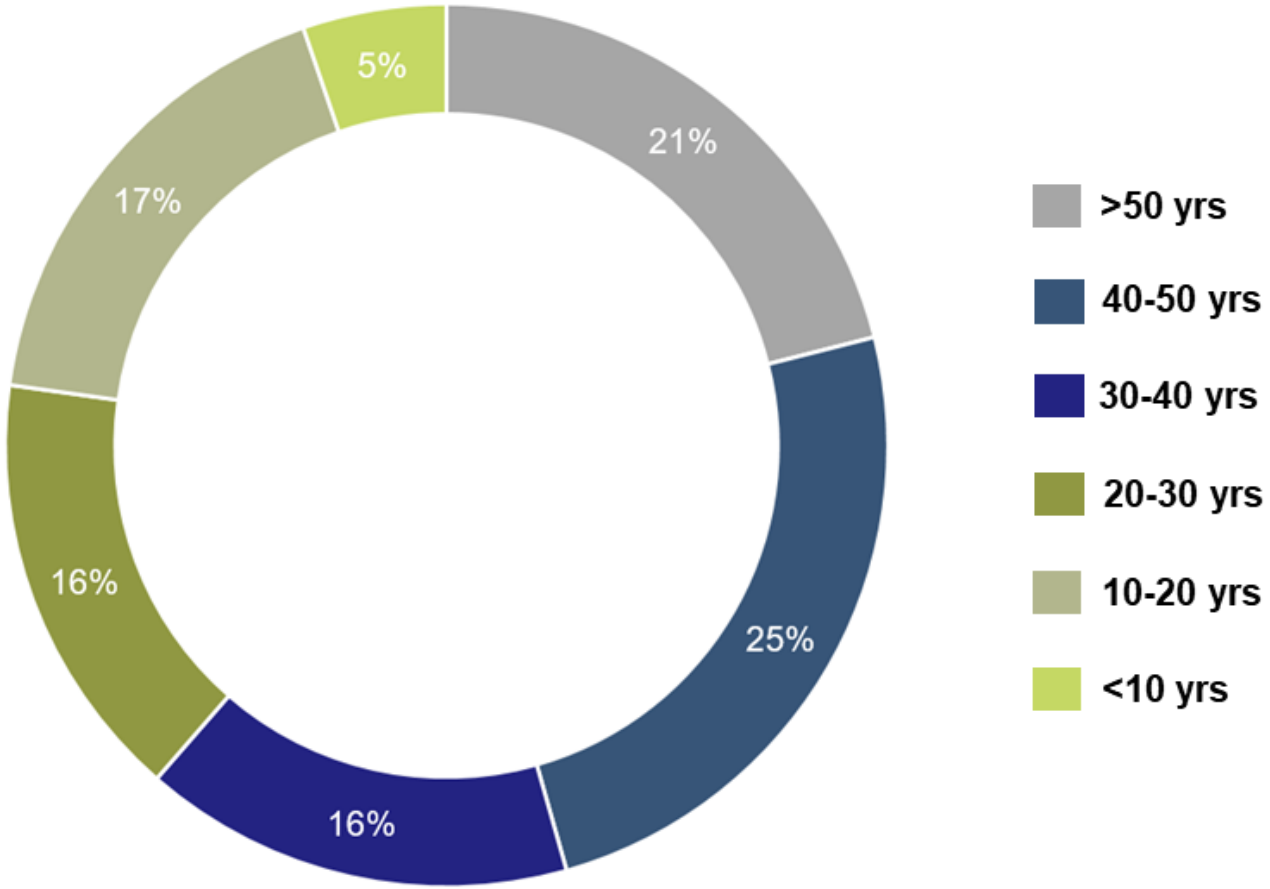
The DNA of Natural Gas Transmission Pipelines & Existing crack threats

THE AGE OF NATURAL GAS TRANSMISSION LINES IN EUROPE



STEEL GRADES IN NATURAL GAS TRANSMISSION LINES IN EUROPE

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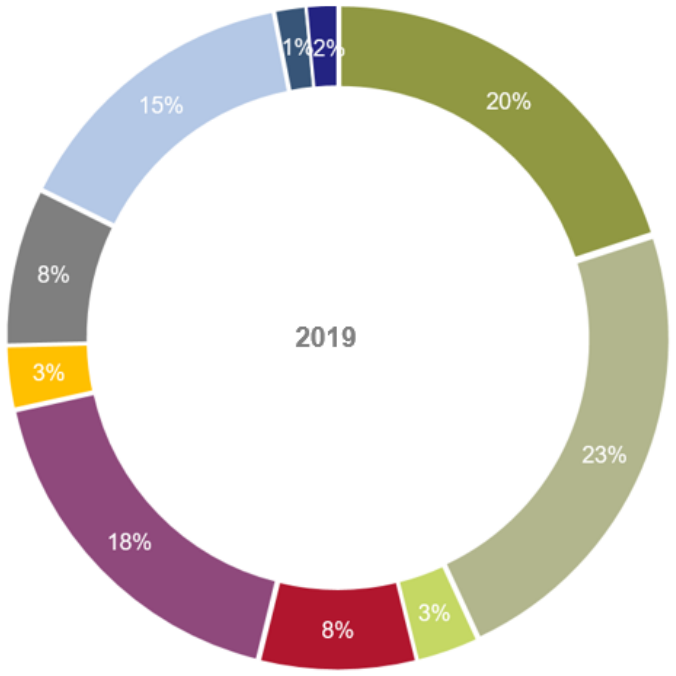
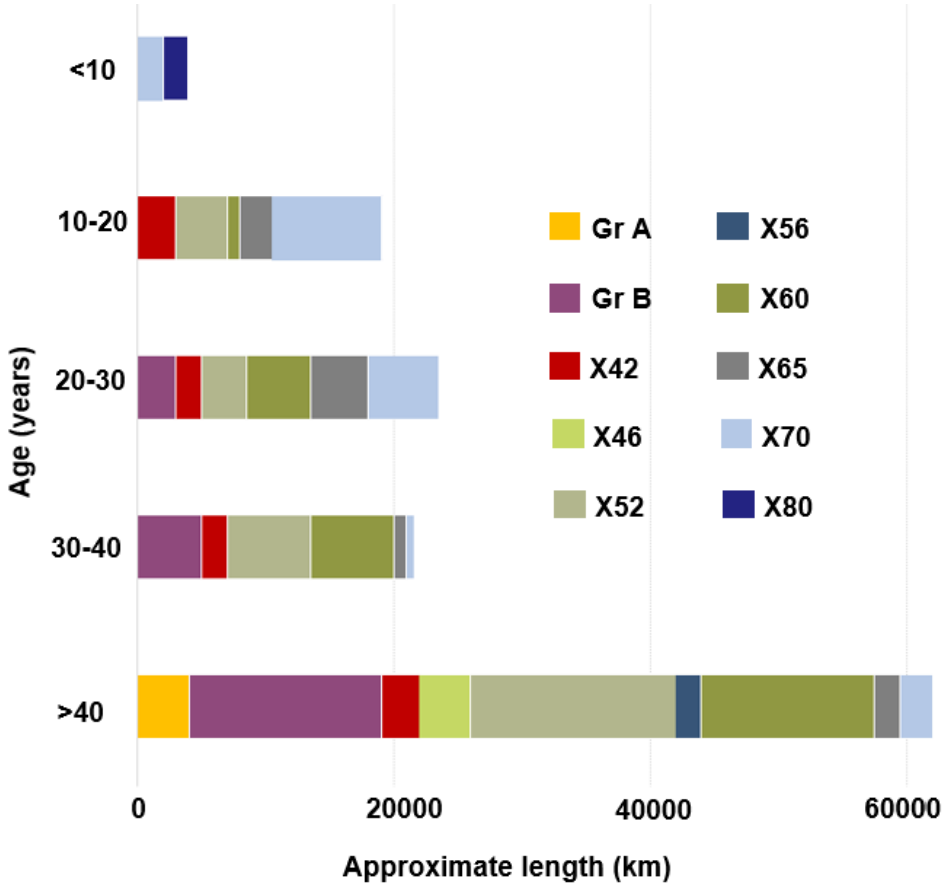
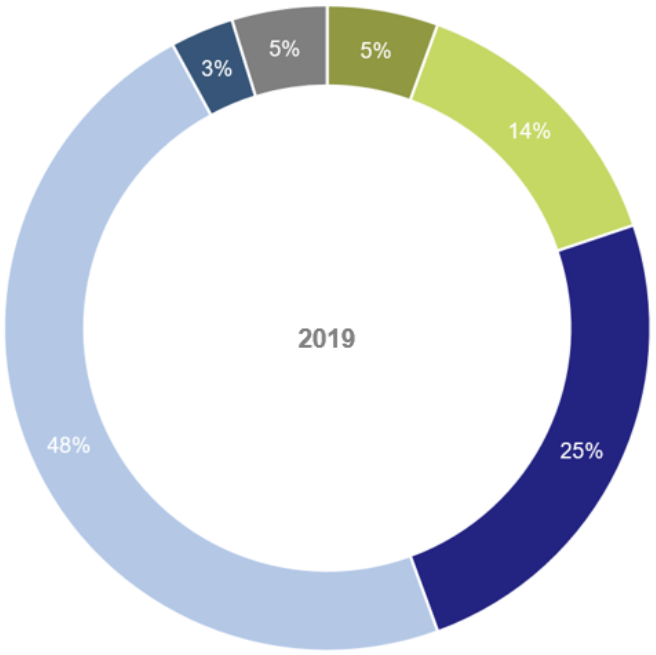
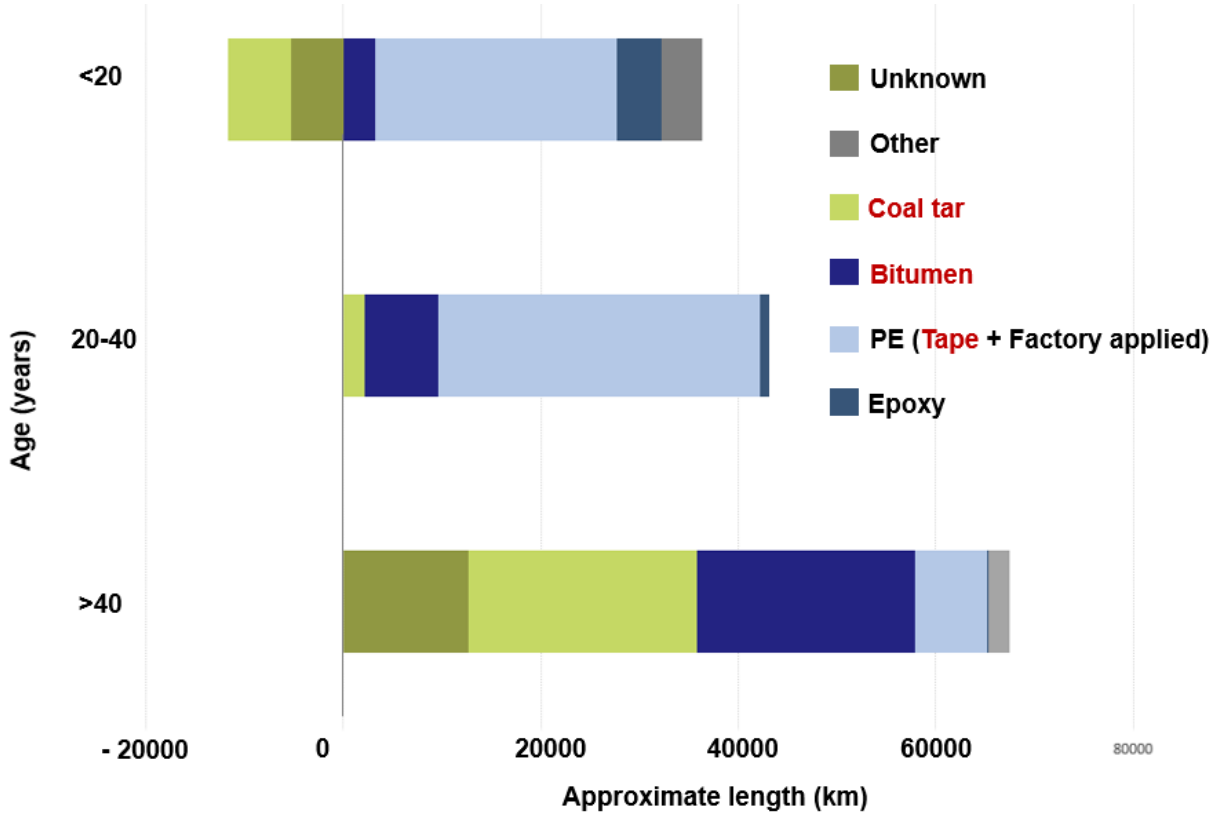




Caution! (SMYS vs AYS)

COATINGS IN NATURAL GAS TRANSMISSION LINES IN EUROPE





FAILURE CAUSES IN NATURAL GAS TRANSMISSION LINES IN EUROPE

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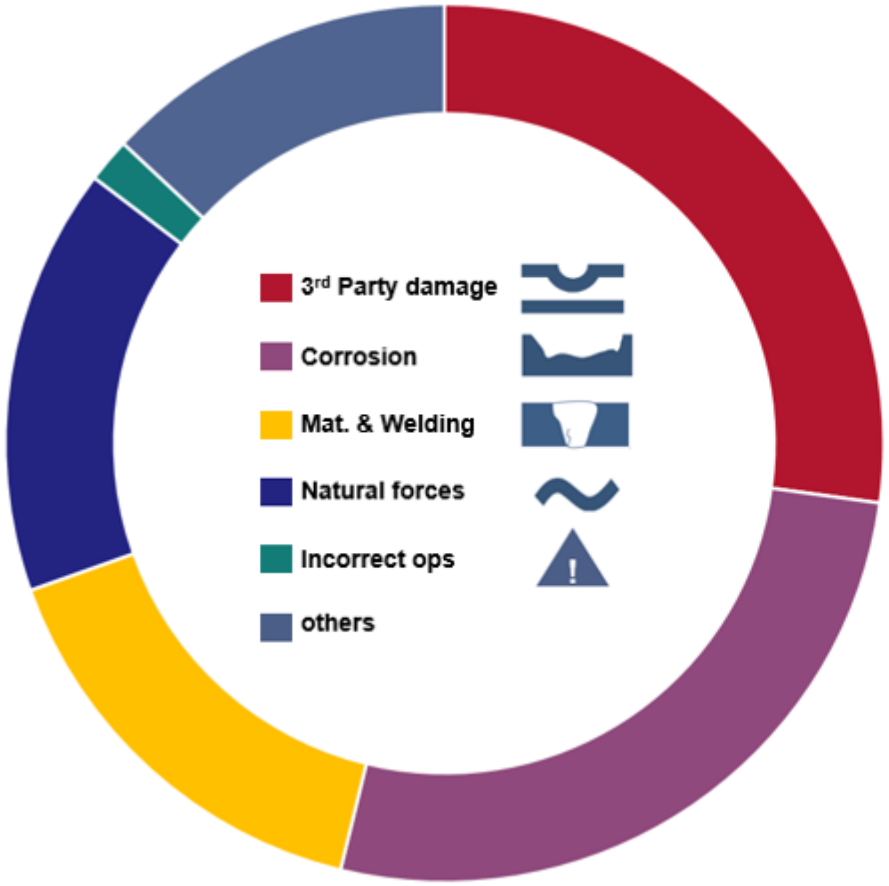
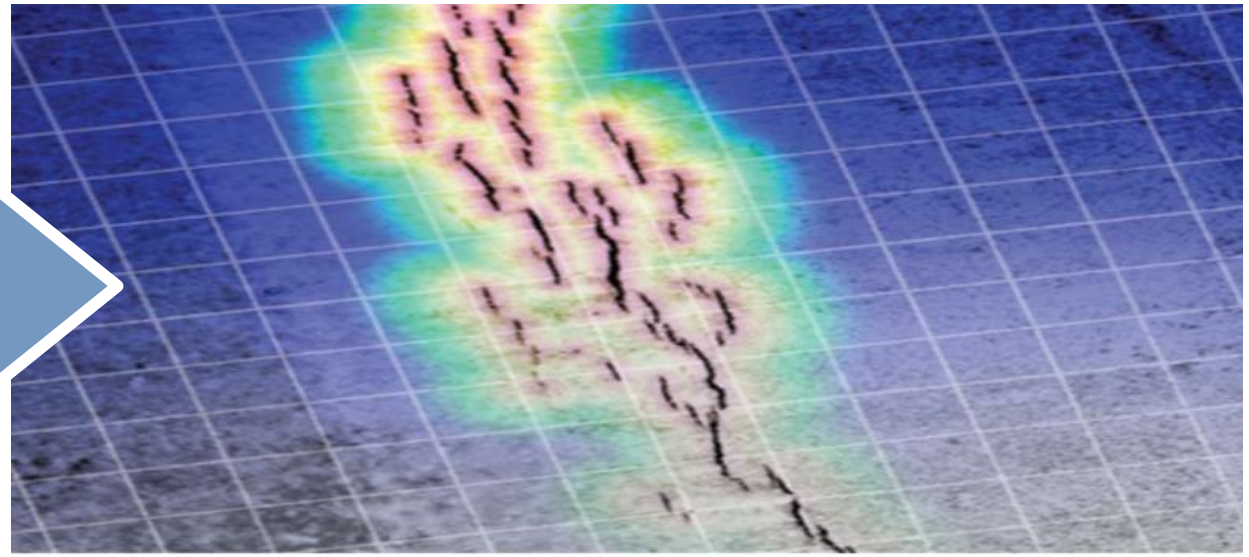
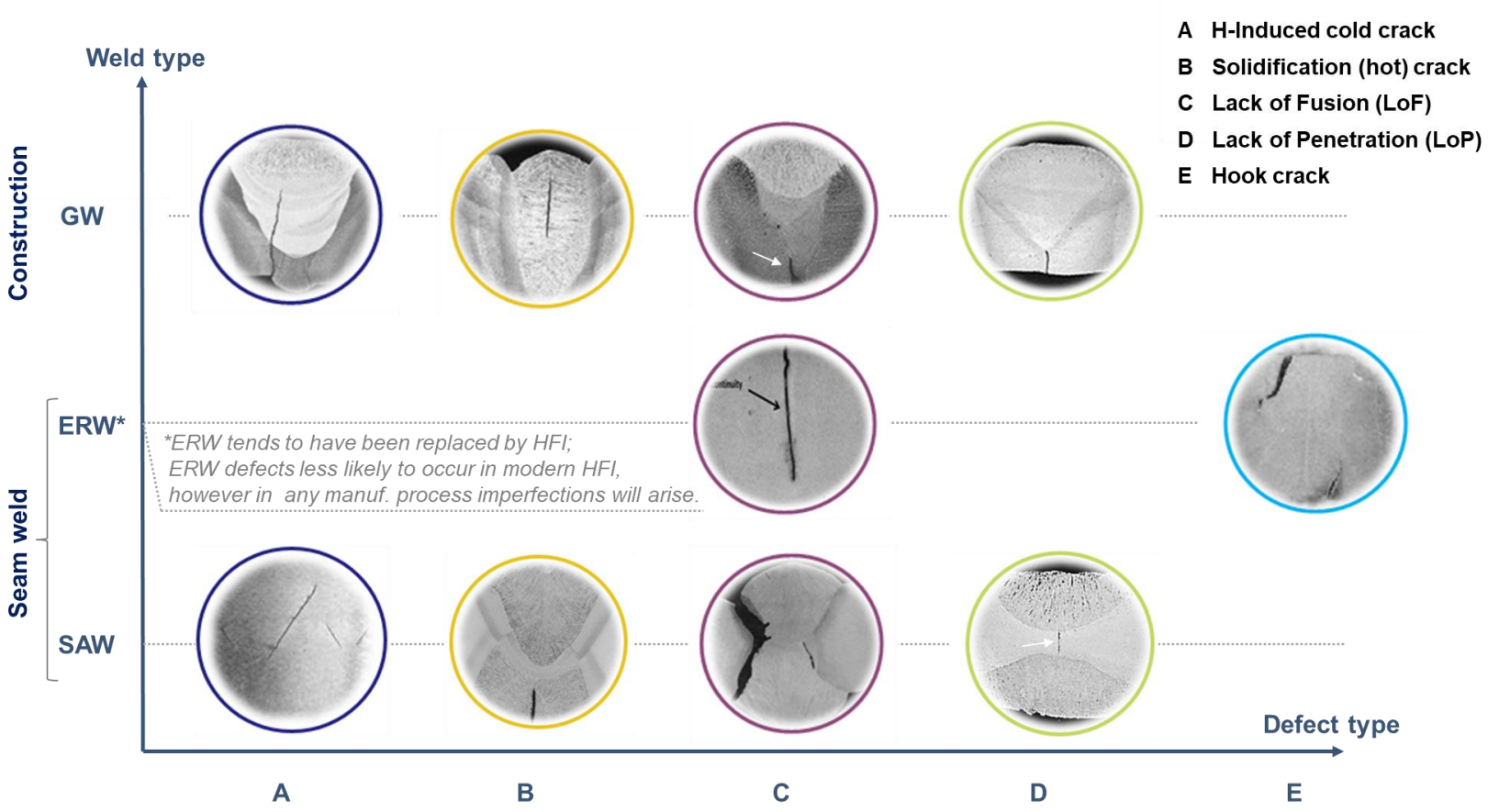




EU NATURAL GAS TRANSMISSION… EXISTING CRACK THREATS?



Fatigue not an issue

NG ≠ Hydrogen

EU NATURAL GAS TRANSMISSION… EXISTING CRACK THREATS?

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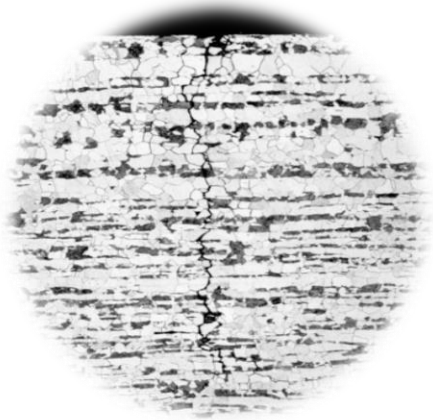
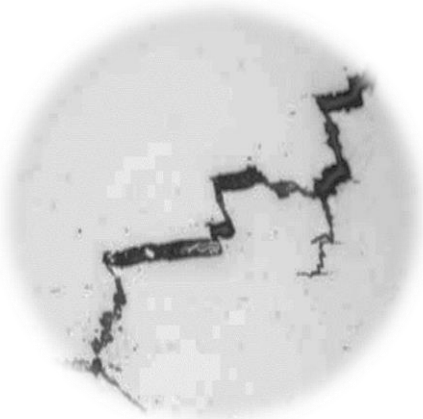
External SCC



HpH SCC.

NNpH SCC.

Hydrogen-Cracking due to CP



HIC

HISC

Impact of gaseous H_2?

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Hydrogen transport …Crack Threats?

H_2 TRANSPORT… SUSCEPTIBILITY VS MICROSTRUCTURE

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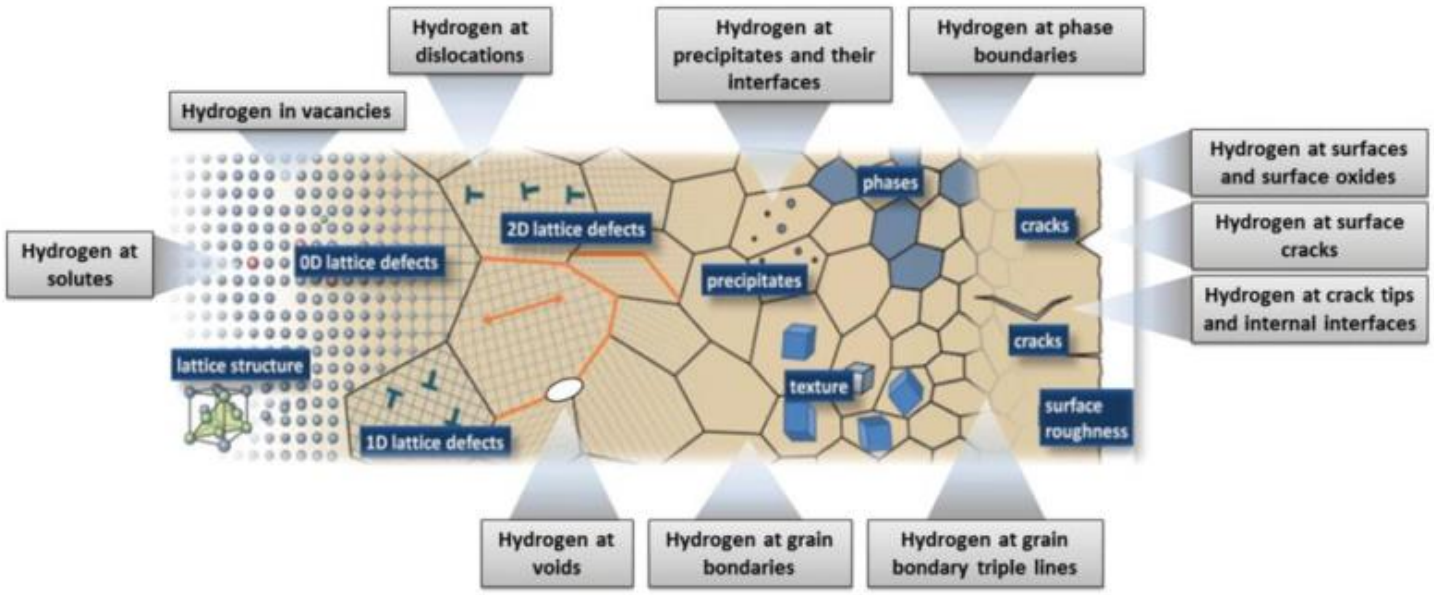
Hydrogen Interaction

Koyama et al.



Interaction
vs Steel Materials..

..Microstructure driven!...
(Not just grade!)

Don’t assume lower bound Properties!

H_2 TRANSPORT…
IMPACT ON MECHANICAL PROPERTIES

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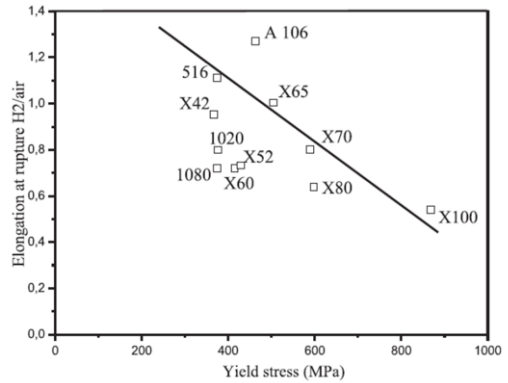
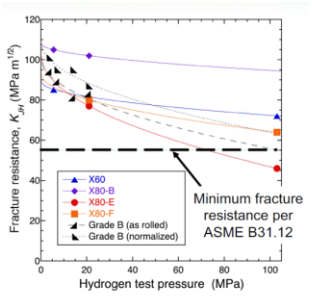
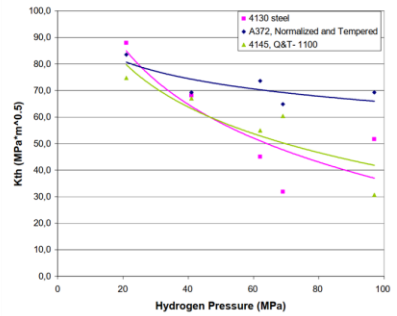
Property	Effect of Hydrogen
Strength	↔ (?)
Ductility	↓
Fracture Toughness	↓
Fatigue Crack Growth Rate	↑



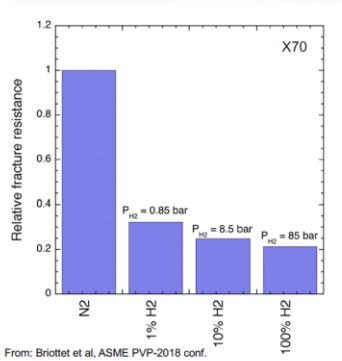
From Boukortt et al., Hydrogen Embrittlement Effect on the Structural Integrity of an API 5L X52 Steel Pipeline, International Journal of Hydrogen Energy, 2018



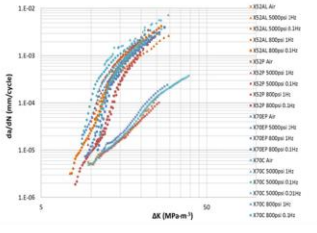
From: San Marchi et al. ASME PVP-1011 conf.

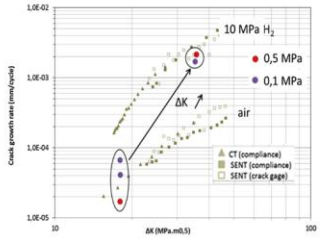


From: Barthelemy, Effects of Purity and Pressure on the Hydrogen Embrittlement of Steels and Other Metallic Materials,
http://conference.ing.unipi.it/ichs2009/images/stories/papers/149.pdf

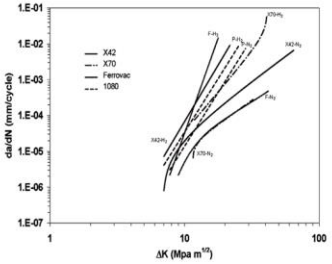


From: Briottet et al, ASME PVP-2018 conf.


From: Chen et al., Performance Evaluation of High-Pressure Gaseous Hydrogen Transportation, CRES Report 2013.



From Briottet et al., Fatigue Crack Initiation and Growth in a CrMo Steel Under Hydrogen Pressure, International Journal of Hydrogen Energy, 2015.

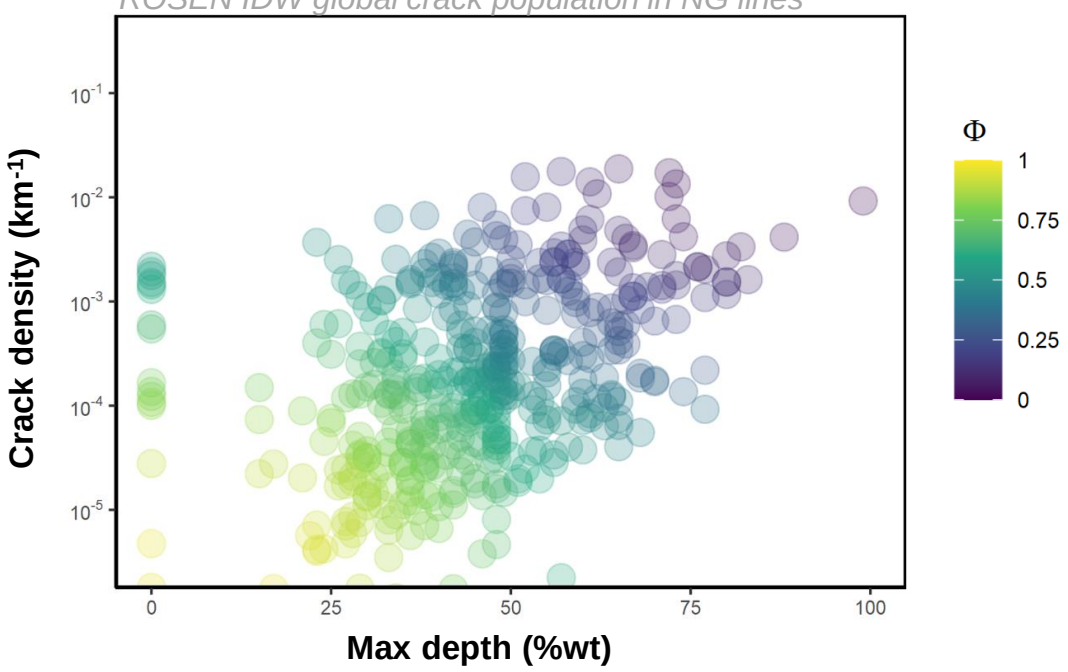


From Nanninga et al., A review of Fatigue Crack Growth for Pipeline Steels Exposed to Hydrogen, NIST Journal, 2010.

H_2 TRANSPORT… NEW CRACK THREATS?

HEAC

ROSEN IDW global crack population in NG lines



The metrics are ranked and normalized based on their positions (percentiles) within the sample, resulting in normalized metric values between 0 and 1. The ϕ value is calculated as a weighted average between normalized feature density and normalizedmaximum depth, subtracted from a value of 1, i.e. Φ= 1 - 0.5 (feature density$_{norm}$ + maximum depth$_{norm}$)

Hydrogen-Environment Assisted Cracking

Growth solely at pre-existing cracks under static stress

…Threshold SIF criteria?...

H_2 TRANSPORT… NEW CRACK THREATS?

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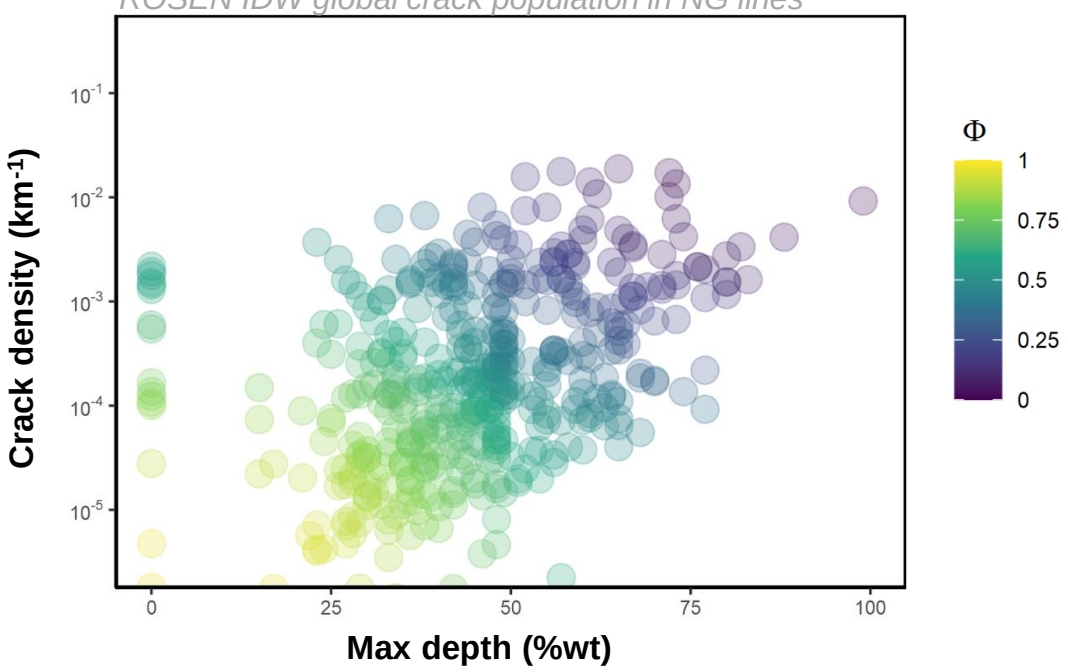
Fatigue

ROSEN IDW global crack population in NG lines



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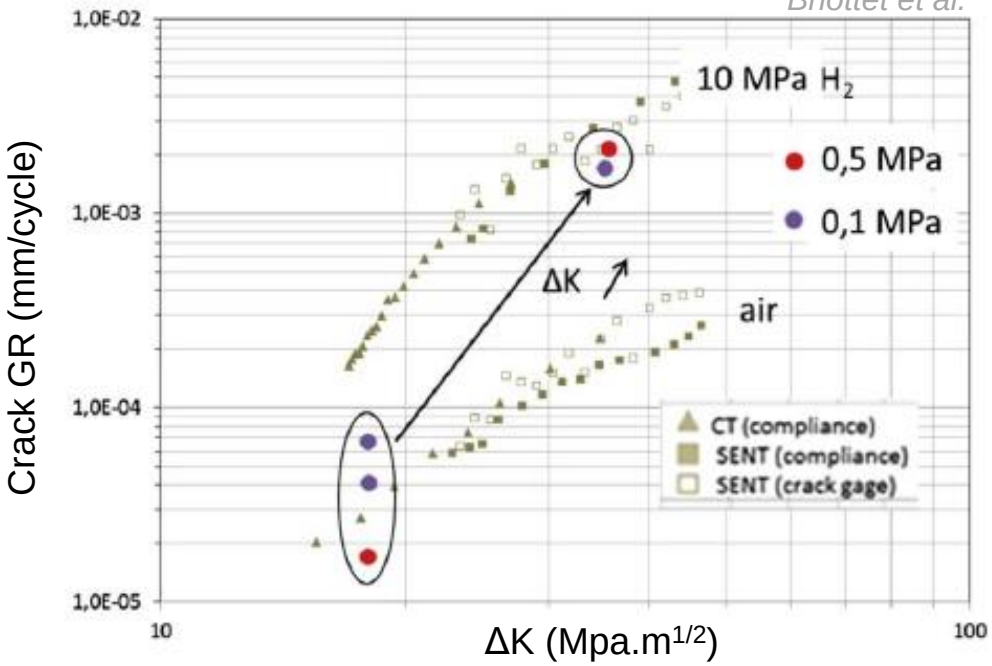
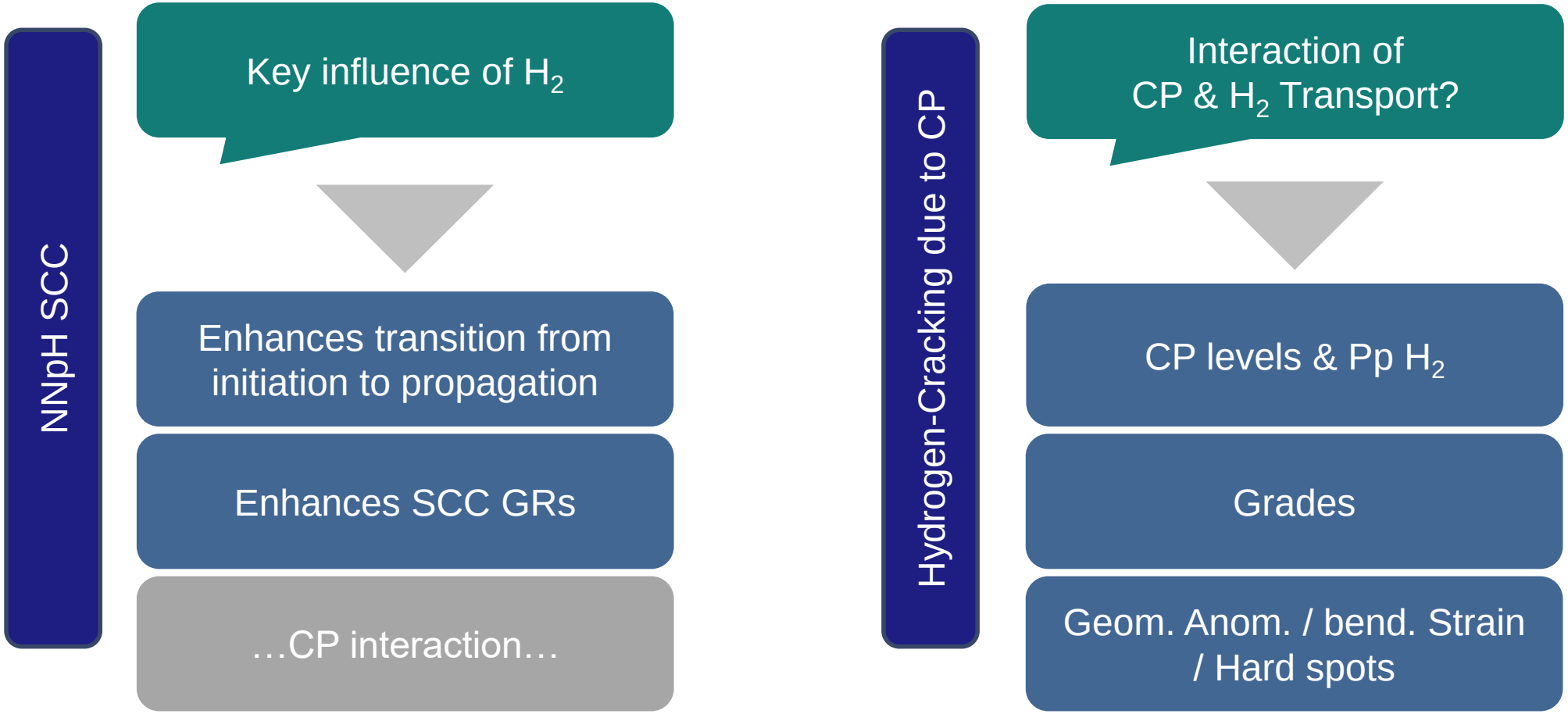
Briottet et al.



H_2 TRANSPORT… INFLUENCE ON EXISTING CRACK THREATS?

Gaps… Threat Quantification?
Expects escalation



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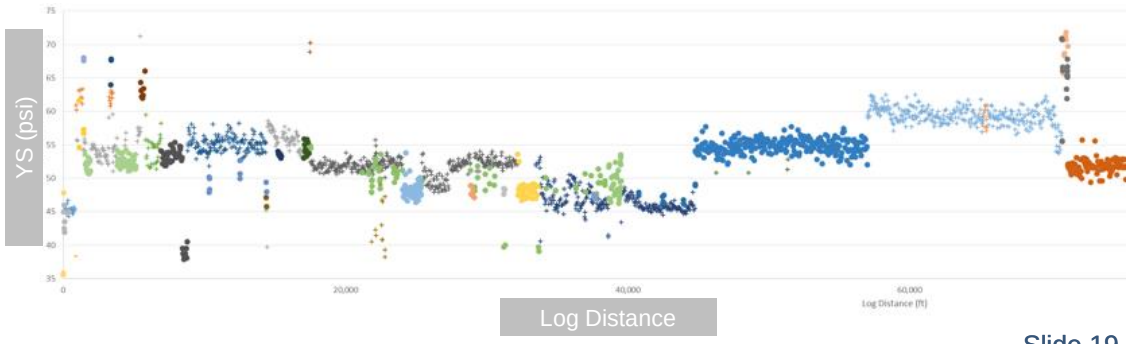
Impact of Hydrogen on Crack Management

H_2 TRANSPORT… THREAT ASSESSMENT

Understand your *materials*

"Targeted Smarter Sampling"

Testing



H_2 TRANSPORT… THREAT ASSESSMENT

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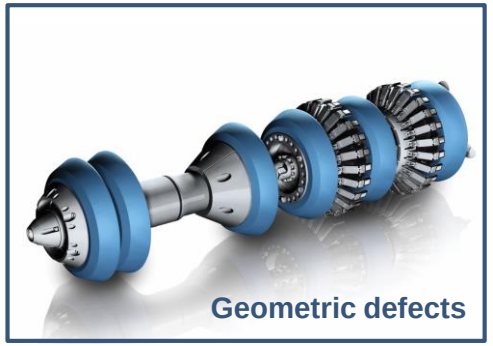
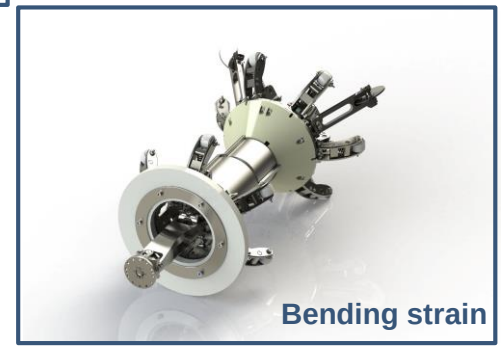
Understand your '*hot spots*'

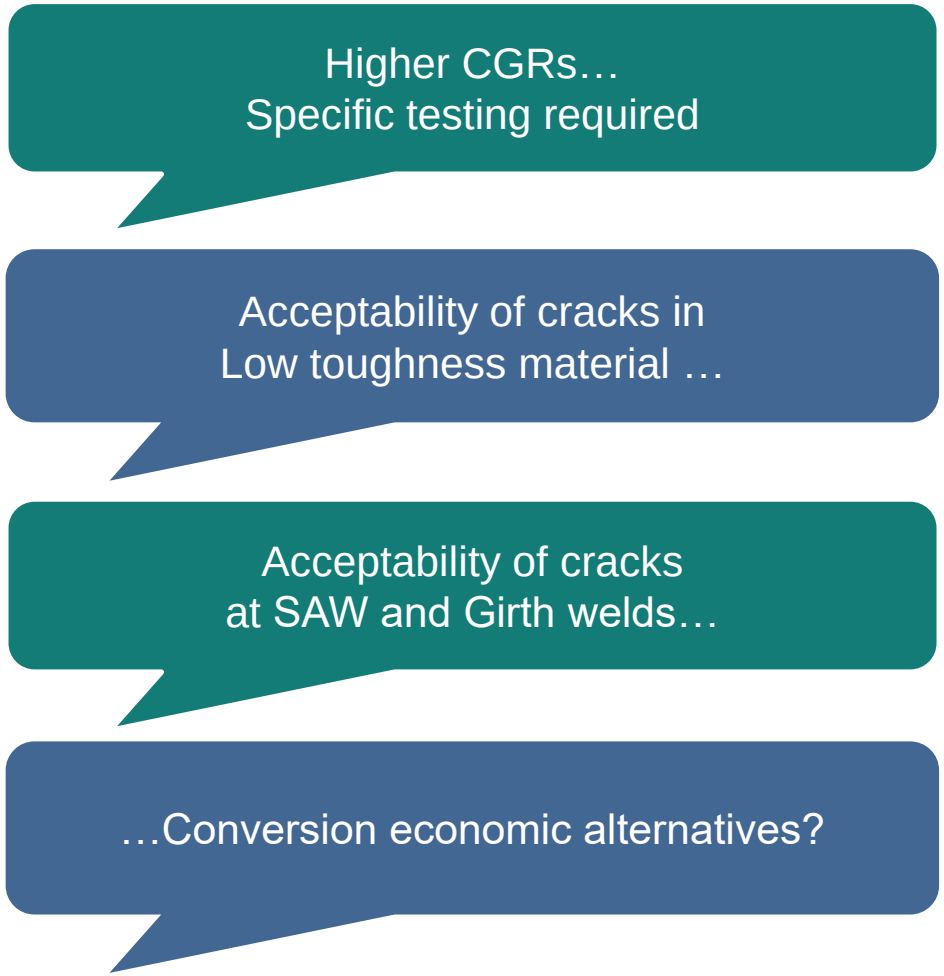
"Targeted Smarter Sampling"

Testing





H_2 TRANSPORT… INTEGRITY & ERL



H_2 Transport …. Crack management

X –Not suitable for conversion
-Review ops constraints
-Pipeline rehabilitation strategy

Conversion strategy

Evaluation of Pre-existing crack threats (NG ops)

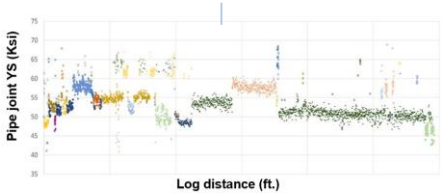
Materials Population

Hard spots

Other key considerations:
- High Bending strain sites
- Geometric anomalies

Baseline crack ILI

Targeted Material Sampling



Expected Hydrogen Operational Framework

Data integration

Testing

Threat assessment
Critical Flaw Analysis
Growth rates

Eng. Analysis

Fatigue
Ext. SCC
HISC & HIC
HEAC (static load)

H conversion suitability

Suitable for H conversion

Future Pipeline Integrity Management

Inspection & Integrity assessment

CP

Additional sampling & testing

Repairs

Type & frequency?

Acceptable CP criteria?

Conclusions

Crack Management Complex topic
…NG vs Hydrogen…

Prexisting crack threats
Escalation…Quantification?

- *Ext SCC (NNpH, HpH)*
- *CP-related H Cracking*

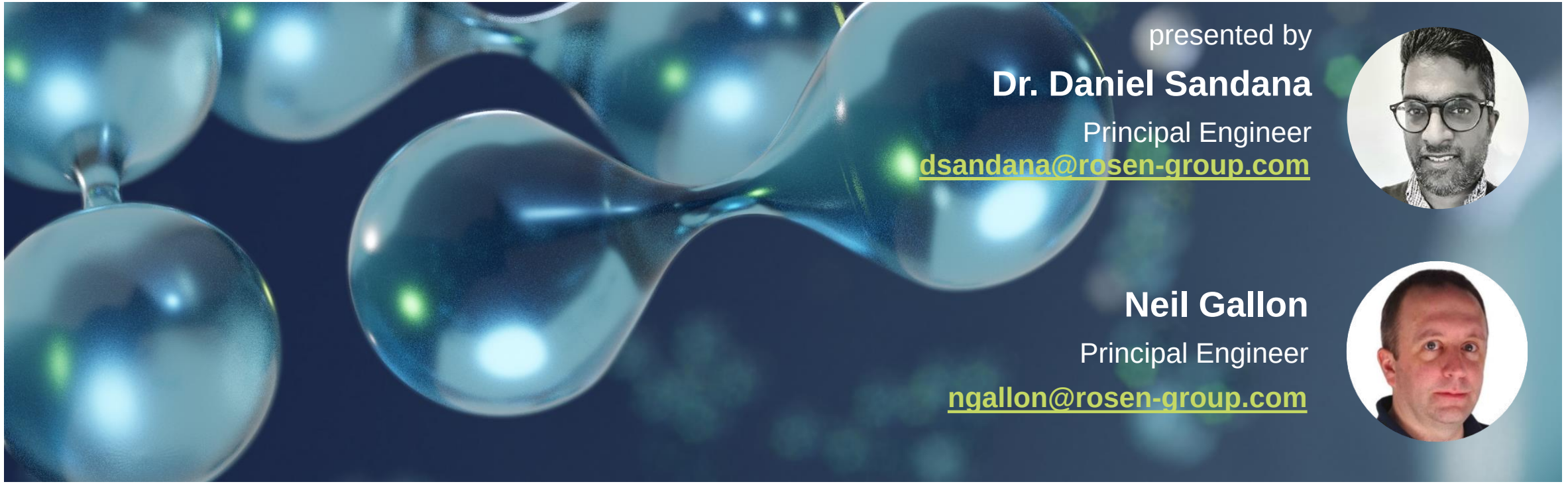
…New threats...
HEAC and Fatigue
…Gaps…

…Understand your materials…

…Understand your Hot spots…
Hard spots, bending strain, geometric, etc.

Targeted sampling & Testing

- *Crack threat susceptibilities*
- *Growth rates*



THANK YOU FOR JOINING!

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