STEEL SUSCEPTIBILITY TO HYDROGEN INDUCED FAILURE

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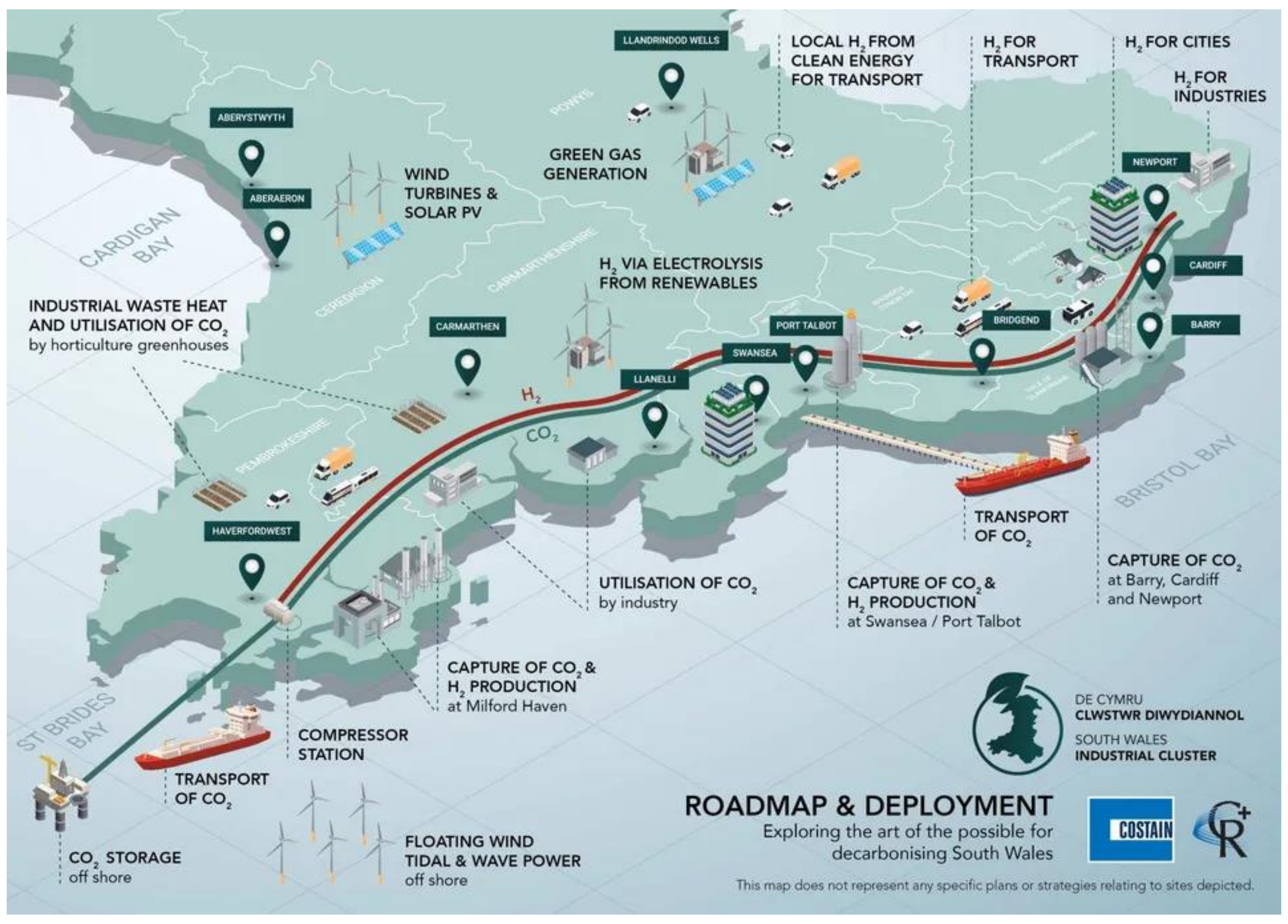
INTRODUCTION



Hydrogen will play an important role in the decarbonisation of sectors that cannot rely exclusively in electrification (e.g. transportation, energy and carbon intensive industries) [1].

The strong investment verified in large-scale projects like HyNet or South Wales Industrial Cluster (SWIC) indicates that soon it will be necessary to reform and expand the current gas transportation and storage infrastructure, to accommodate high volumes of pure or blended hydrogen.

Two crucial elements of that infrastructure are steel ***pipelines*** and ***pressure vessels***, which are particularly susceptible to hydrogen induced failure (HIF), an unpredictable phenomena that often leads to substantial economic losses and environmental damages.

Table1: Typical steel grades for pipeline and pressure applications [2,3].

Steel grade	Mass fraction (%), max. value					Yield strength (MPa, min)	Tensile strength (MPa)	Elongation (%)
	C	Mn	P	S	Si			
X52 to X70*	0.28	1.40	0.030	0.030		290-485	415-570	
P235GH, P265GH	0.16	0.6-1.2	0.025	0.010	0.350	235	360-480	24

* Nb + V + Ti ≤ 0.15%

INTERACTION OF HYDROGEN WITH METALS

Table 2: Differences expected in HIF caused by internal hydrogen and hydrogen environment [4].

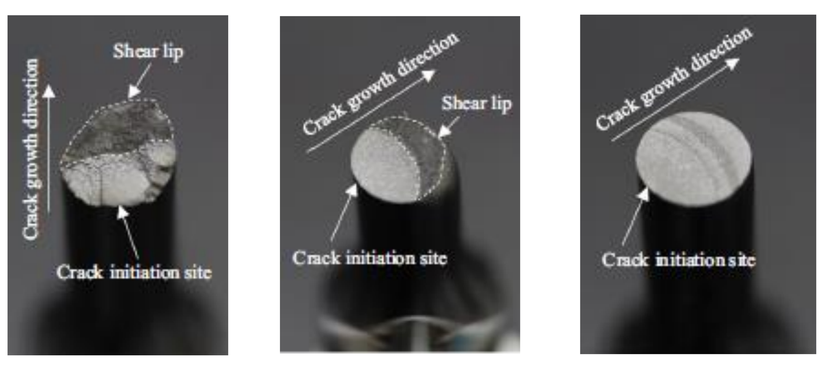
Parameter	**Internal Hydrogen** Contained in interstitial solid solution during manufacturing or corrosion	**Hydrogen Environment** Takes place when metal is stressed in high-pressure hydrogen
Delayed Failure Tests	Embrittled	Not embrittled
Crack Origin	Subsurface (inside metal)	At surface
Crack Rate Dependency	Hydrogen diffusion	Hydrogen adsorption
Surface Cracking	Not observed	Observed in unnotched specimens

Factors that lead to pipeline and pressure vessels failure:

- Higher strength steels are more susceptible to hydrogen damage
- Elevated internal pressure and cyclic stresses
- Corrosion

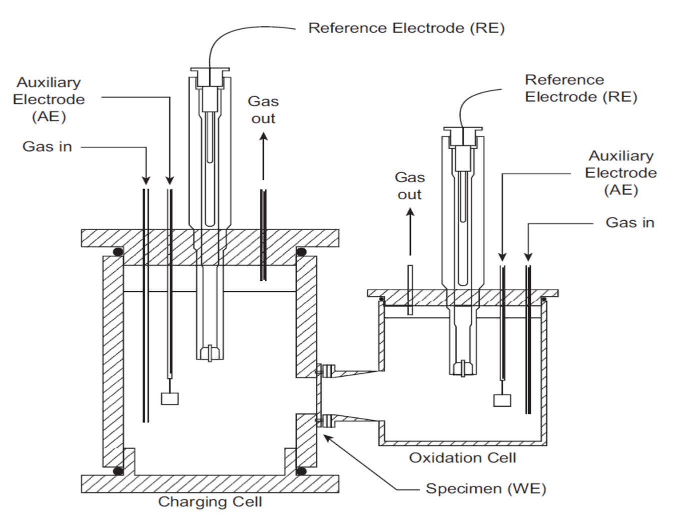
RESEARCH PROJECT OUTCOMES

- Characterization of microstructure, corrosion properties and evaluation of mechanical properties degradation in contact with hydrogen.



Air | 0.7MPa H_2 | 115MPa H_2

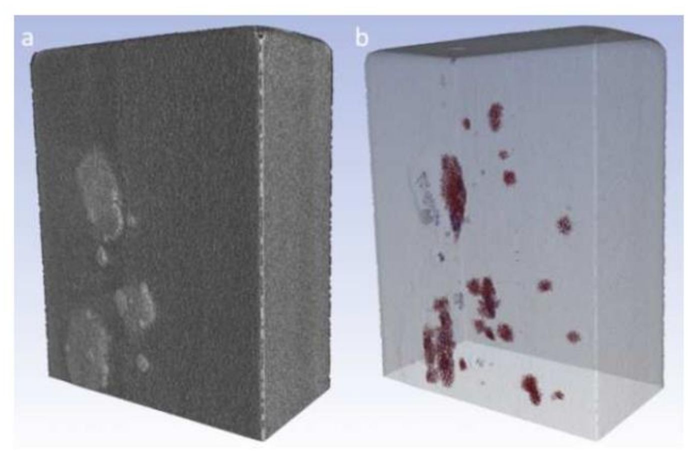
Fatigue fracture surfaces of JIS-SM490B steel round-bar specimens, broken at σ_a of 320MPa (R=-1, f=1 Hz) [5].



Hydrogen permeation testing setup, according to ISO 17081:2014 [6].

- Study of hydrogen transport characteristics, for different service conditions (temperature fluctuations, pressure).

- Understand hydrogen atomic distribution using conventional and advanced state of the art techniques.



Reconstructed 3D model (neutron tomography) of a hydrogen charged iron sample [7].

REFERENCES

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