Summary:

The European Commission has drawn up a roadmap for making the EU economy sustainable in the "European Green Deal". Offshore energy production from windmills and tidal power plants, and its distribution through pipelines, is a key component of the green energy budget, which will require reliable and advanced subsea equipment. Knowledge of the integrity of components, equipment and pipes under real exposure conditions is of key importance to ensure safe utilization of offshore rigs and distribution networks.

Hydrogen embrittlement is a long-standing challenge for the offshore energy industry and, more generally, for the hydrogen economy. It is becoming increasingly critical due to aging infrastructure and the need to develop life-extension strategies. When subsea structures are exposed to seawater, atomic hydrogen is absorbed into metallic components and causes material degradation (hydrogen embrittlement) that may lead to premature failure with catastrophic consequences. To date, there is no established standard that dictates how hydrogen embrittlement testing should be conducted, and the existing experimental test procedures are costly and time consuming, resulting in a paucity of data. There is also limited understanding of the micromechanical mechanisms through which loading and different environmental conditions affect hydrogen uptake and embrittlement in structural metals, which impedes rational material selection and utilization in structural design.

We propose to address this knowledge gap through the following research thrusts: (i) Characterization of hydrogen uptake and diffusion into highstrength steels under realistic environmental conditions of temperature, hydrostatic pressure and electrochemical potential using advanced atomistic models and long-term simulation capability; (ii) Characterization of the extent of decohesion due to hydrogen seggregation to grain boundaries using advanced atomistic models and realistic grain-boundary geometries; (iii) Coupled multiscale analysis of structural components, including plasticity, based on the material characteristics determined in (i-ii); (iv) Verification and validation of the multiscale model against experimental data and elucidation of design tradoffs. One tangible outcome of this research will be open-source simulation framework enabling researchers and engineers to bridge the mesoscopic predictive gap between fundamental processes and properties at the atomic scale and structural-level full life-cycle operation. We also expect the methodological and knowledge-based generated by the project to contribute significantly to the fundamental and applied understanding of hydrogen embrittlement in offshore structures, thus in turn contributing to safeguarding existing and future offshore infrastructure. We expect the results of the project to be also relevant and beneficial generally to all industries where hydrogen uptake can be detrimental to structural integrity, safety, and operability.