VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Emile Beckwée**

The public defense will take place on **Thursday 11th September 2025 at 5 pm** in room **D.2.01** (Building D, VUB Main Campus)

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ENHANCING HYDRATE-BASED CH_4 AND H_2 STORAGE BY CONFINEMENT

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Abstract of the PhD research

The growing global population is driving energy demand to unprecedented levels, making the shift to clean, renewable energy sources more urgent than ever. The intermittent nature of renewables, fluctuations in energy supply and demand, and geopolitical issues necessitate energy to be stored over time. Methane (CH_4) and hydrogen (H_2) are two important chemical energy carriers that are produced from biomass or renewable electricity. Traditional storage of these carriers is based on compression to high pressure or liquefaction at low temperature, rendering safe and energy-efficient storage major technological bottlenecks. Gas hydrates are crystalline compounds, built up from cages of water molecules, that encapsulate gas molecules upon their formation. Recently, they have received increased attention as storage medium due to their large storage capacity, non-explosivity, environmental friendliness, moderate formation conditions and low risk of handling. However, hydrate-based gas storage is hampered by intrinsically slow formation rates, restricting practical deployment today.

This doctoral thesis investigates the use of porous materials to enhance methane and hydrogen hydrate formation for storage and separation applications. Porous materials provide a large surface area for water dispersion, aiding the overall rate and extent of water-to-hydrate conversion, and thus gas storage. First, both classical and novel techniques for gas hydrate quantification are reviewed and a novel unambiguous means of reporting hydrate performance is introduced. Next, various mesoporous solids are evaluated for hydrogen and methane storage, revealing unique (re)crystallization kinetics and operating conditions. Finally, the focus is shifted from the material-level to the system-level, combining macroporous melamine foam with a surfactant to achieve dense hydrate packings with enhanced water-to-hydrate conversion and high selectivity.

Overall, this work reviewed and developed hydrate quantification techniques, introduced a novel framework for evaluating hydrate performance and screened various meso- and macroporous materials for CH_4 and H_2 storage and separation.