VRIJE UNIVERSITEIT BRUSSEL

UNIVERSITÉ LIBRE DE BRUXELLES

The faculty of Engineering of the Vrije Universiteit Brussel and the École Polytechnique de Bruxelles of the Université libre de Bruxelles invite you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES (VUB)

DOCTEUR EN SCIENCES DE L'INGÉNIEUR ET TECHNOLOGIE (ULB)

of **Kevin Verleysen**

The public defense will take place on **Wednesday 1st February 2023 at 5:00pm** in room **D.0.08** (Building **D**, Brussels Humanities, Sciences & Engineering Campus)

To join the digital defense, please contact Kevin via kevin.verleysen@vub.be

ROBUST DESIGN OPTIMIZATION OF POWER-TO-AMMONIA PROCESS FOR SEASONAL HYDROGEN STORAGE

BOARD OF EXAMINERS

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Abstract of the PhD research

Ammonia as an energy carrier boomed in recent years because it can transport renewable-based hydrogen over large distances. In addition, ammonia can be used as a fuel by cracking it partially or entirely into hydrogen. Therefore, producing ammonia in large mass is needed to support the defossilisation of the world. Furthermore, ammonia is an essential product in the fertilizer industry, where this sector currently uses steam reforming for hydrogen production; emitting carbon emissions during the process. Therefore, replacing fossil-fueled production of nitrogen fertilizers with renewable ones would directly impact the carbon emission within our food chain. However, the transition towards renewable ammonia is covered by uncertainties. These uncertainties range from economics (capital and operational expenses of electrolyzers) to technical (compressor efficiency) to the security of energy supply (availability of wind and solar power). These uncertainties could significantly impact the cost, performance and production of a renewable-based ammonia synthesis plant as the traditional ammonia synthesis process is not adapted for this erratic and uncertain operation. If we incorporate these uncertainties during the design optimization via an uncertainty quantification analysis, we can select an ammonia plant that is least sensitive, i.e. robust, towards the implemented uncertainties. Sensitivity indexes, i.e. Sobol' indices, quantify the impact of uncertainties on these plants where a design can be selected based on the impact on the chosen performance indicator's mean and standard deviation.

The thesis focused on various performance indicators for each case, e.g. the levelized cost of ammonia, energy efficiency, ammonia production, flexibility and resilience; besides, we used steady-state and dynamic models with low- and high-fidelity results to investigate their sensitivity toward time-invariant and -variant uncertainties. This work shows the advantage of using the robust design optimization on the highly non-linear Haber-Bosch synthesis loop in combination with the implemented economic, technical and operational uncertainties. These uncertainties significantly impact the cost and performance, and provide knowledge on the most sensitive part of the ammonia production process.