TEA HybSi®

Techno-economic evaluation of solvent dehydration by HybSi® pervaporation membranes

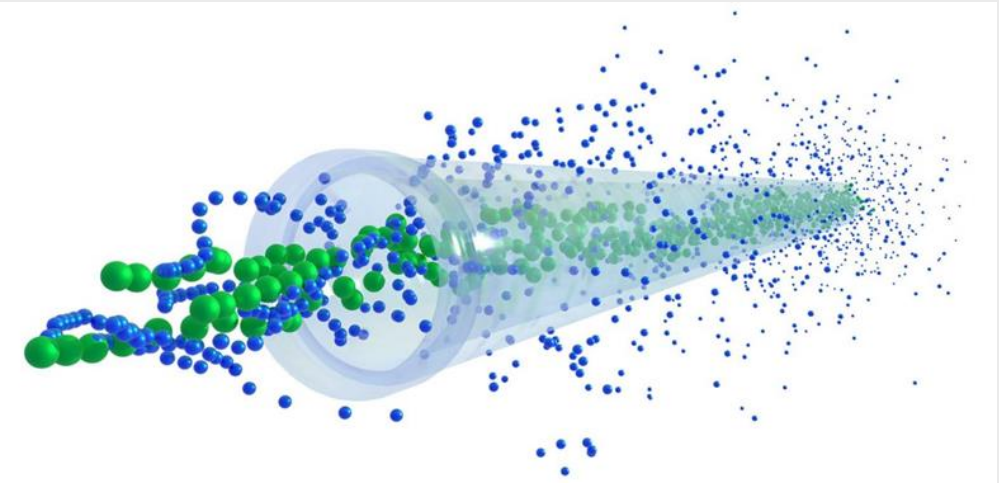
The project assesses the economic feasibility of solvent dehydration by (hybrid) pervaporation instead of benchmark distillation

THE CONTEXT

Re-use of solvents is an important objective in many industries, e.g. pharmaceutical, chemical, bio-tech and paint. The objectives are to improve sustainability and circularity, as well as to save in operational cost and to reduce carbon footprint.

Distillation is commonly used for solvent recovery or dehydration. However, in cases where azeotropes are present, or in case of close boiling points, simple distillation to complete purification is not possible or highly energy and CAPEX intensive. In such cases, a hybrid process of distillation and pervaporation or a pure pervaporation process can be attractive alternatives. CAPEX and energy reductions in the order of 40% can be achieved, leading to a significant CO_2 footprint reduction.

Pervatech developed and commercializes unique, robust, ceramic Hybrid Silica HybSi® Acid Resistant membranes, designed to separate water and other polar compounds out of a mixture of liquids. They are perfectly fit for a variety of dehydrations, at high throughput.



HybSi® ceramic membrane technology and industrial HybSi® modules for solvent dehydration applications: www.hybsi.com

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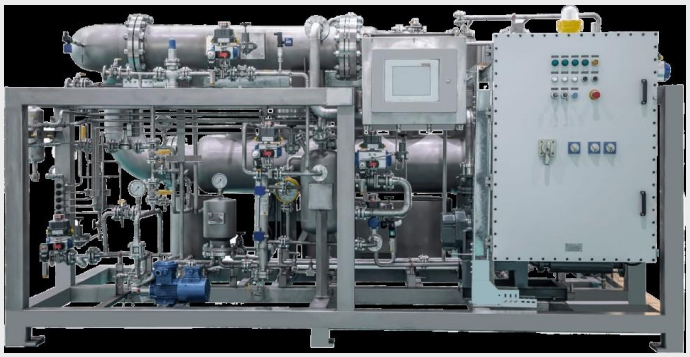
THE CHALLENGE

The TEA HybSi® project aims to provide a techno-economical comparison between benchmark (azeotropic) distillation, pervaporation or hybrid processes based on both technologies, and this for the dehydration of selected, industrially relevant liquid mixtures. The analysis will be made both on investments (CAPEX) as well as on operational costs (OPEX), in which energy consumption is the main cost component. This will be achieved by simulations and model calculations of benchmark distillation and alternative pervaporation processes, for a few representative water/solvent mixtures. The project will specifically use data from Pervatech's HybSi® membranes, provided by Pervatech.

The techno-economical analysis (TEA) results of this project, are intended to further push the market uptake of HybSi® membranes for dehydration applications relevant to chemical, pharma, food and biotech processing. Moreover, the project results aim to steer which dehydration issues are best solved using HybSi® membranes, and will pinpoint and quantify the energy/cost gains and CO_2 footprint reduction. All results will be made openly available via publication, and will be used to direct Pervatech's marketing efforts.



Hybrid distillation-pervaporation for IPA dehydration (left) and Pervatech pervaporation pilot (right)

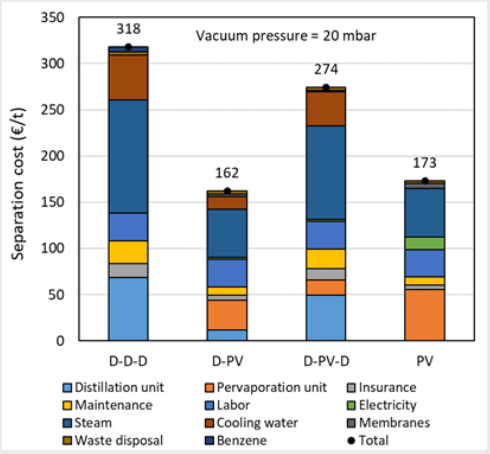
THE RESULTS

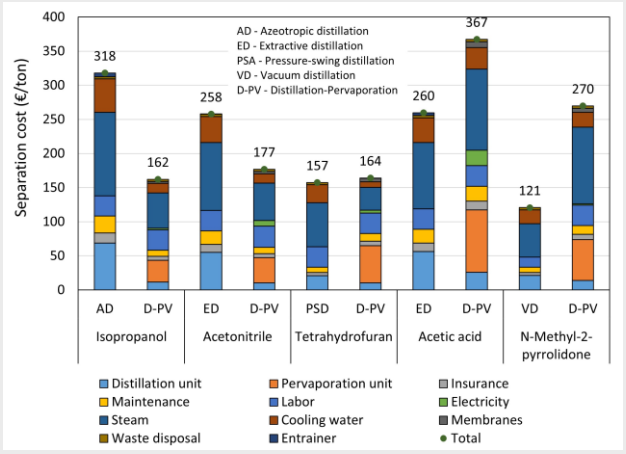
TEA was performed for five industrially relevant solvent dehydration cases: isopropanol (IPA), acetonitrile, tetrahydrofuran (THF), acetic acid, and n-methylpyrrolidone (NMP). Feed flow rate was defined at 1000 kg/h at 20°C and 1 bar, feed composition was 50/50 wt%, and product purity fixed at 99,5 wt%.

All common equipment such as distillation columns, heat exchangers, condensers, pumps were modelled in Aspen Plus. Pervaporation modelling was performed using experimental data of Pervatech as input in an own TEA tool developed at VITO.

CAPEX and OPEX were calculated and compared for 4 scenario's: benchmark azeotropic (or extractive) distillation (D), hybrid distillation – pervaporation (D-PV), hybrid distillation – pervaporation – distillation (D-PV-D) and standalone pervaporation (PV). In the hybrid processes, pervaporation is used to break the azeotrope.

Sensitivity analysis allowed to define the most influencing cost parameters. And based on the energy use, CO_2 impact was calculated for all scenario's.





Separation costs for different scenario's for dehydration of IPA/water (left) and other mixtures

CONCLUSION

TEA analysis was successfully performed for the dehydration of five industrially relevant feed mixtures, and showed that:

- To dehydrate solvents as IPA or acetonitrile, pure pervaporation or hybrid distillation-pervaporation with the HybSi® membranes of Pervatech leads to much lower CAPEX and separation costs compared to the benchmark azeotropic distillation (> 45%, KPI1)
- CO_2 footprint is reduced in all cases (up to 86%, KPI2)
- The purified solvent yield and thus solvent recovery for all pervaporation process is high (> 90% , KPI3)
- The pervaporation process with HybSi® is very selective for water in all cases: water content > 99% (KPI4)
- For dehydration of high boiling solvents as NMP and acetic acid, pervaporation is not the most economical option, but offers the possibility to work at lower temperatures and for lower feed flows.

TECHNIQUES USED

The TEA HybSi® project used the following services and capabilities of the INNOMEM OITB:

- Techno-economic assessment of distillation and membrane-based processes, available within the INNOMEM OITB, and here performed by partner VITO.

For more information, you can get in touch with us by sending an email to anita.buekenhoudt@vito.be or info@pervatech.nl