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Membrane separations and energy efficiency: a critical overview

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Membrane processes are usually considered to offer very promising potentialities in terms of energy efficiency for industrial separations [1-2]. This statement particularly holds for homogeneous gas and liquid separations which are traditionally performed thanks to unit operations based on a phase change (distillation, evaporation, condensation, crystallization…). The energy efficiency concept can however be addressed through different methodologies, potentially leading to different, if not opposite conclusions [3]. A critical analysis of the energy efficiency concept for membrane separations is proposed. Starting from the most usual minimal work of separation definition [4], alternative expressions of this key concept are developed in order to better reflect the different types of separation situations encountered for practical purposes (solute purification and/or recovery, process selectivity). In a second step, the real work of separation of a given process, classically evaluated through modern Process Systems Engineering computations, including thermodynamic modelling and irreversibilities, is discussed. The interest of the entropy dissipation function, obtained from Irreversible Processes Thermodynamics (IPT, [5]) approach is then presented. The methodology is applied to different case studies. The local entropy dissipation rate offers the opportunity to analyze the impact of fluid distribution in membrane modules, possibly leading to improved designs through the entropy equipartition theory. The largely unexplored possibilities of IPT to provide a predictive evaluation of the overall energy efficiency of a separation process, based on a diffusional mass transfer mechanism [6], is finally illustrated.

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Eric Favre is chemical engineering professor at the Ecole Nationale Supérieure des Industries Chimiques (ENSIC) and member of the executive committee at Université de Lorraine, France. He holds a PhD in chemical engineering from INPL (Nancy). His research activities on separation processes started first at EPFL (Switzerland) on membrane bioreactors and at the Department of Chemical Engineering and Materials Science at the University of Minnesota (USA), where he was a visiting scientist in 1989. Since 1998, he is based at the *Laboratoire Réactions et Génie des Procédés*[1], CNRS, Nancy. His current research activities cover chemical engineering studies of gas and liquid separation processes, mostly through dense polymeric membranes and gels including phase equilibria thermodynamics, mass transfer processes, energy efficiency, green engineering and intensification issues. Eric Favre is the author of more than 110 publications in scientific journals, 6 book chapters, 10 patents, 3 licences, he is deputy president of the French membrane society (Club Français des Membranes) and a founding member of the *Fondation Ensic*[2]. He is a member of the editorial board of the *Journal of Membrane Science* since 2005[3] and of the journals *Membranes* and *Membrane Science & Technology*. He received the French Society of Chemical Engineering award in 1994, the Montgolfier Prize in 1998 and a national teaching award (Palmes Académiques) in 2006.

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[1] http://lrgp.univ-lorraine.fr/

[2] http://www.fondationdefrance.org/fondation/fondation-ensic

[3] https://www.elsevier.com/journals/journal-of-membrane-science