US Department of Energy's Workshop on Separation Processes and Membrane Technologies

June 26, 2017

Stakeholder Workshop Summary – National Renewable Energy Laboratory

Summary

On June 8, 2017, Navigant Consulting, Inc. and the National Renewable Energy Laboratory (NREL), on behalf of the U.S. Department of Energy's (DOE) Building Technologies Office (BTO), hosted a stakeholder discussion workshop to identify research and development (R&D) needs and critical knowledge-gaps related to separation processes and membrane technologies. DOE convened this stakeholder workshop to gather input on potential research opportunities at the TRL-2 and TRL-3 stages.[1] The concepts and initiative ideas gathered during this workshop will help guide a roadmap for DOE to support research to foster advancements in membrane and separations applications.

BTO hosted the workshop at NREL. Thirty-nine stakeholders participated, including university researchers, national laboratories, manufacturers, and representatives from industry organizations. A list of attendees and their affiliations is included in the Appendix.

Objective

BTO's objective for this workshop was to gather input on where the greatest opportunities exist for both membrane and separations technologies and use this information to prepare a prioritized list of potential initiatives that can aid BTO in achieving their goals.

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[1] For more information on Technology Readiness Levels (TRLs), please refer to the US DOE Technology Readiness Assessment available at: https://energy.gov/sites/prod/files/em/Volume_I/O_SRP.pdf

Process and Results

Discussions at the workshop included large-group discussions as well as smaller breakout-group sessions. Each attendee participated in two small-group discussions, with each group of participants discussing slightly differing topic-areas for the second session. During the first session, attendees:

- Discussed concepts, enabling science, and applications that can result in membrane/separation-based energy savings in building technologies.
- Developed a list of potential initiatives

Between the first and second session, stakeholders had the opportunity to engage in a round of preliminary prioritization by voting on their top-five initiatives.

The second breakout session focused on exploring, in greater detail, the top nine initiatives emerging from the preliminary-prioritization process. These discussions sought to:

- Refine initiative title and objective(s)
- Identify detailed technical challenges
- Determine most promising applications
- Identify partnership and collaboration opportunities
- Characterize desired high-level outcomes (both energy and non-energy benefits)

The first breakout session generated a total of 43 research activities (technology opportunities) for BTO to consider (hereafter "initiatives"). Participants ranked the ideas by voting on the ones that they felt were most valuable and promising for BTO to undertake. Each participant received 5 votes to distribute among the different initiatives as they saw fit (regardless of topic area).

The following table documents each proposed initiative, along with the number of votes[2] it received. This table reflects the raw outputs of the workshop so items in the table may overlap or require further processing, but provide documentation of the conversations that transpired during the session.

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[2] The total number of votes does not equal 5 votes/person multiplied by 39 attendees because: 1) Some attendees departed prior to voting; 2) the workshop facilitators did not vote.

Table 1: Technology Initiatives from the First Breakout-Session

Initiative	Votes
Establish building-challenge-focused targets (e.g., air quality targets) for membranes in specific applications - follow up with membrane characteristic-based targets.	12
Develop new materials or material processing techniques that hit cost targets, using a systems approach with interdisciplinary teams	11
Develop modeling tools for design of heat and mass exchangers	10
Develop membranes for VOC and/or CO_2 removal for Indoor air Quality (IAQ)	8
Standardized test-method development for membranes, including mass transfer metrics and mechanical properties	8
Develop multi-functional membranes that work in many applications	8
Systems understanding top-down analysis to inform research and leverage multi-functionality	7
Develop self-healing membranes	6
Development of hybrid membranes (not just all organic/polymeric)	6
Solar-based dehumidification for buildings (enabled by metal-organic frameworks treated as an adsorbent)	6
Optimize membrane methods/properties for improved bonding	5
Metal-organic frameworks (MOFs) for advanced control of chemical properties	5
Membranes for clean-water extraction during waste-water treatment	5
Develop membranes that allow for high flux	5
Membrane-based heat/energy storage for daily/seasonal cycles	5
Support further development of absorption heat pumps	5
Develop thinner materials that can withstand higher pressure gradients	4
Conduct longevity studies of membrane-based systems	4
Develop cost-effective manufacturing processes for creating drop-in membrane modules (easy to assemble)	4
Develop new, less-energetic separation technologies	4
Membrane-enabled cooling towers using seawater (that manage scale build-up)	4
Develop membrane-based low-cost sensors that discriminate between different pollutants/gases	4
Support development of improved durability and reduced fan-power-loss for membranes for latent-heat removal	3

Initiative	Votes
Develop low-power, long-life sorption/desorption for indoor air quality sensing	3
Support further development of enthalpy exchangers (heat & moisture) for A/C	3
Develop membrane-based heat-recovery systems for flue gasses	3
Tailoring membrane structures, with polymers of commerce (commodity materials), to reach reasonably optimal properties	3
Evaluate opportunities for improving membrane strength and durability	3
Develop fouling-resistant membranes	3
Insitu membranes grown directly on a porous support (for mechanical integrity only)	2
Develop membranes to minimize thermal losses in buildings	2
Develop error-proof vapor-permeable envelope air-barriers	2
Develop membrane-enabled design guide	2
Water selectivity for high-permeance membranes (at high RH)	2
Development of leak-proof hollow-fiber membranes	1
Develop membranes to handle more varied permeates (particularly vacuum permeate)	1
Incorporation of biologics (robust geometries/materials in nature and integrate them)	1
Develop integrated 2-phase materials (e.g. materials with one phase supporting structure and another supporting transport)	1
Develop membrane-based VOC sensors	1
Testing for scale-up of membrane applications.	1
Minimize pressure drops in filtration processes	1
Identify and develop low-cost sensors for dynamic process control	0
Membrane moisture-recovery in polluted airstreams (lab vent-hoods)	0

Next Steps

Navigant, in conjunction with BTO, will continue to refine and develop these initiatives though additional research and follow-up interviews with individual stakeholders who were unable to attend the workshop. Navigant will produce a roadmap report that recommends to DOE the initiatives to consider pursuing, based on some or all of the following criteria:

- Fit with BTO mission

- Criticality of DOE involvement

- Impact

- Time to impact

- Stakeholder input (including voting results)

DOE will consider the recommended outputs of these prioritization processes for funding in parallel with other priorities in other building end-use areas. Therefore, no recommended output from this opportunity assessment is guaranteed to receive DOE support.

The workshop outputs, incorporated into Navigant's future roadmap report, will serve as a guide for DOE and its partners to increase support of membrane and separation technologies while maintaining the competitiveness of American industry.

Appendix: Workshop Attendees

Navigant and DOE wish to thank all of the workshop participants. The suggestions, insights, and feedback provided during the workshop are critically important to identifying and prioritizing membrane and separations initiatives.

The stakeholder discussion workshop brought together 39 individuals representing a range of organizations across the industry. Table 2 lists all the attendees and their affiliations.

Table 2: Stakeholder Workshop Attendee List

Attendee Name	Organization
Omar Abdelaziz	Oak Ridge National Laboratory
Bamdad Bahar	Xergy Inc.
Steven Baker	Emerson Climate
Youssef Bargach	Navigant Consulting, Inc.
Daniel Betts	Be Power Tech, Inc.
Uwe Beuscher	WL Gore & Associates
Brian Bischoff	Oak Ridge National Laboratory
Antonio Bouza	US Department of Energy
Mark Buelow	BASF
Frederick Cogswell	United Technologies Research Center
Panos Datskos	Oak Ridge National Laboratory
Steven C. DeCaluwe	Colorado School of Mines
Jason DeGraw	National Renewable Energy Laboratory
Debra Deininger	Integrated Device Technology
Chaiwat Engtrakul	National Renewable Energy Laboratory
Michael Geocaris	US Department of Energy
Bill Goetzler	Navigant Consulting, Inc.
Matt Guernsey	Navigant Consulting, Inc.
Chioke Harris	National Renewable Energy Laboratory
Michael Hu	Oak Ridge National Laboratory
Ryan Huizing	dPoint Technologies
Roderick Jackson	Oak Ridge National Laboratory
Brian Johnson	Dais Analytic Corporation
Eric Kozubal	National Renewable Energy Laboratory
Chuck Kutscher	National Renewable Energy Laboratory
Jason Lustbader	National Renewable Energy Laboratory
Peter Luttik	7AC Technologies
Jeffrey McCutcheon	University of Connecticut
Saeed Moghaddam	University of Florida
Sven Mumme	US Department of Energy
John Pellegrino	University of Colorado

Attendee Name	Organization
Jim Peters	PPG Industries
Sameer Rao	Massachusetts Institute of Technology
Rob Tenent	National Renewable Energy Laboratory
Ed Trudeau	Emerson Climate
Jeffrey Urban	Lawrence Berkeley National Laboratory
Michael Wofsey	US Department of Energy
Jason Woods	National Renewable Energy Laboratory
John Zhai	University of Colorado