



King Abdullah University of  
Science and Technology



# Advanced Membranes and Sorbents for More Sustainable Hydrocarbon Utilization

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# Energy, environmental and purification issues



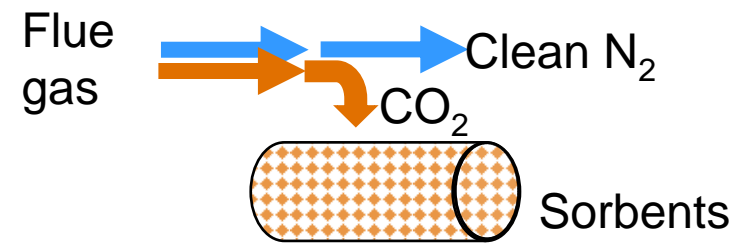
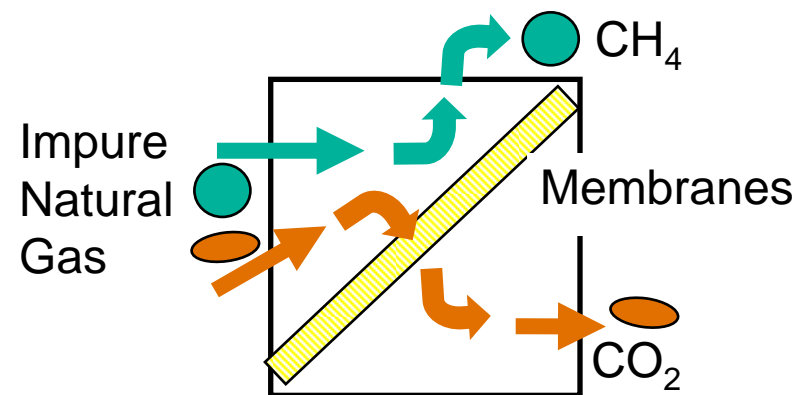
- Purification & separation to produce commodities are energy intensive -- accounting for ~ 15% of global usage in 2008

- Global demands for commodities (water, fuel, chemicals) could escalate in 2040 to 3-4x beyond the demands in 2008
- Using current separation technology, such demand growth would need the equivalent of 45-60% of total 2008 global energy usage

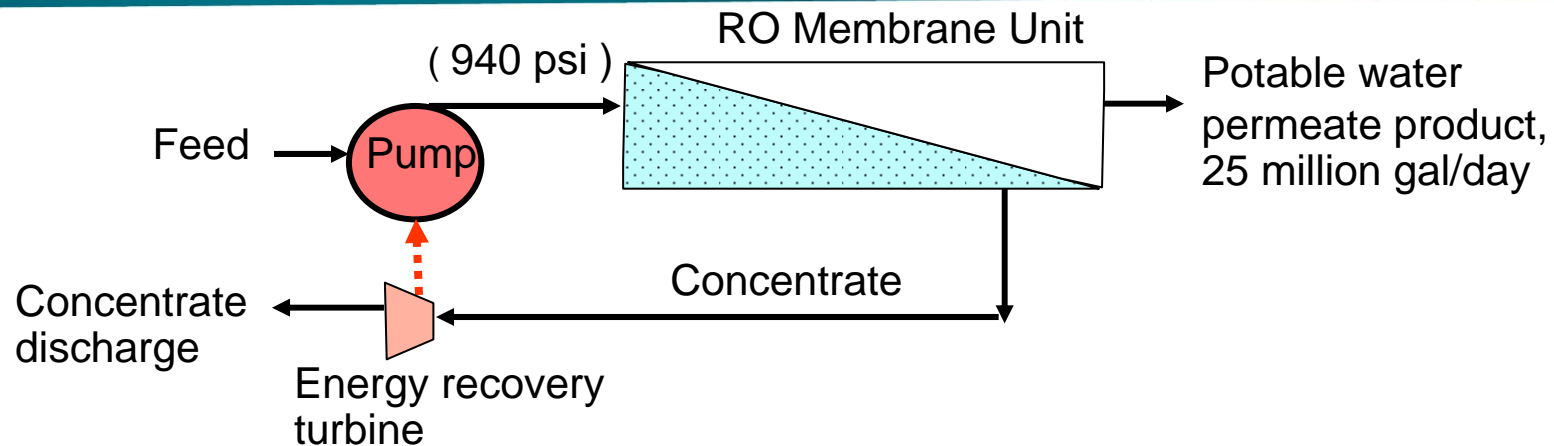
# Energy, environmental and purification issues



- Future global commodity needs will require excessive energy consumption if provided via current separation technology
- Such a “business as usual” approach is a non-sustainable and unwise strategy, since alternatives can be developed
- Engineered membranes & sorbent systems offer a *sustainable alternative strategy* that we will pursue with KAUST



# Reverse Osmosis (RO)– A useful example



RO plants are typically  $> 10 \times$  less energy intensive than thermal evaporation

RO has a huge impact--9 billion gal/day worldwide desalination: 50% thermal and 50% membranes-- and the majority of new plants are RO based

Extending this approach broadly to other micro-molecular separations will be revolutionary... **but it presents a great challenge !**

# Challenges facing the Kingdom– “beyond water”

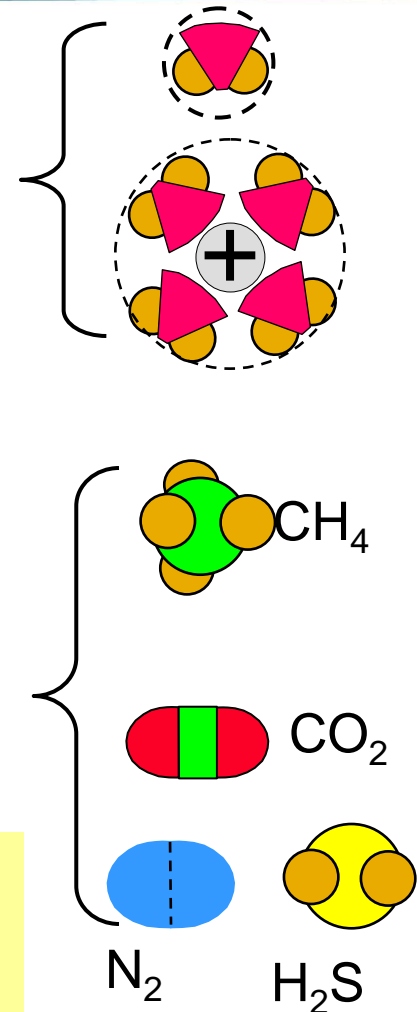


Salt vs. water separation by reverse osmosis is “easy”, since water is ~ 50% smaller in “diffusion size” than hydrated salt ions.

versus ....

CO<sub>2</sub> is only 15% smaller than CH<sub>4</sub> in “diffusion size”, and H<sub>2</sub>S & N<sub>2</sub> are only 4-5 % smaller than CH<sub>4</sub> --- and trillions of cubic feet of natural gas must be purified around the world.

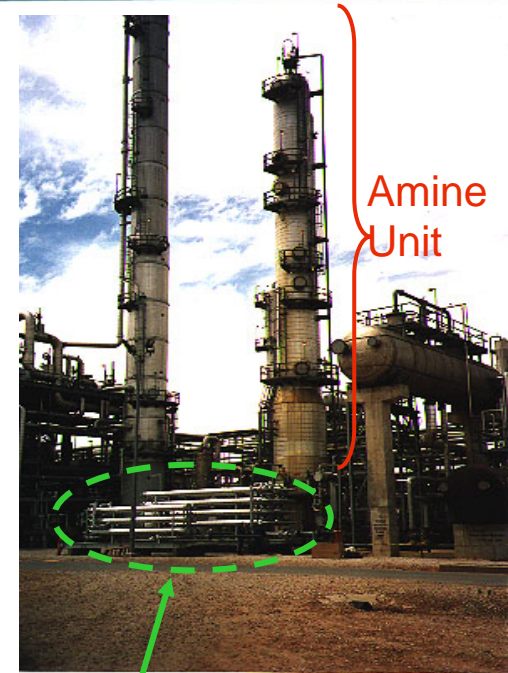
*What is the state of the art in performing these challenging separations, which are of key importance to the Kingdom?*



# Membranes are already having impact



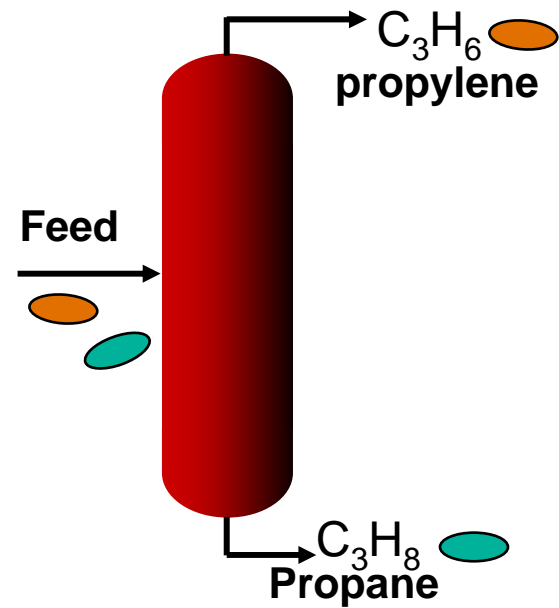
- Membranes offer alternatives to amine scrubbers--- but high  $\text{CO}_2$  feed pressures need more robust and more selective membranes
  - $\text{H}_2\text{S}$  removal with membranes---barely investigated, but potentially quite feasible
  - $\text{N}_2$  removal--- a major challenge using membranes but if  $\text{CH}_4$  can be retained while removing  $\text{N}_2$ , huge energy savings would result vs. current alternatives
- Science and technology of novel membranes for advanced clean up of natural gas in the Kingdom and around the world will be high priority topics of collaborative research with KAUST



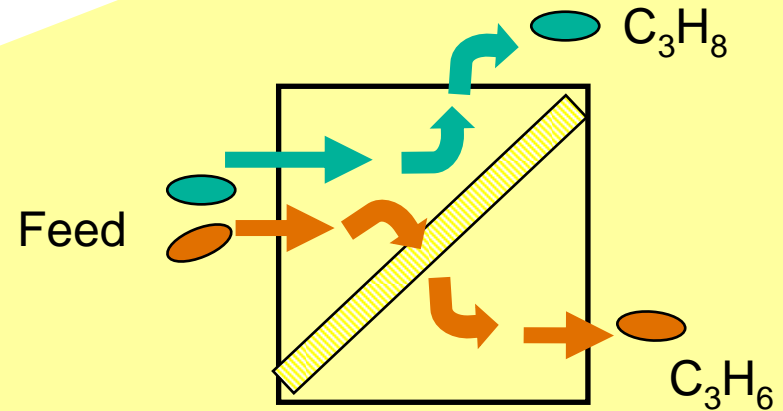
Courtesy of Medal, L. P.

Membrane unit that replaced large amine unit shut down due to corrosion

# Downstream applications: e.g., propylene-propane separation

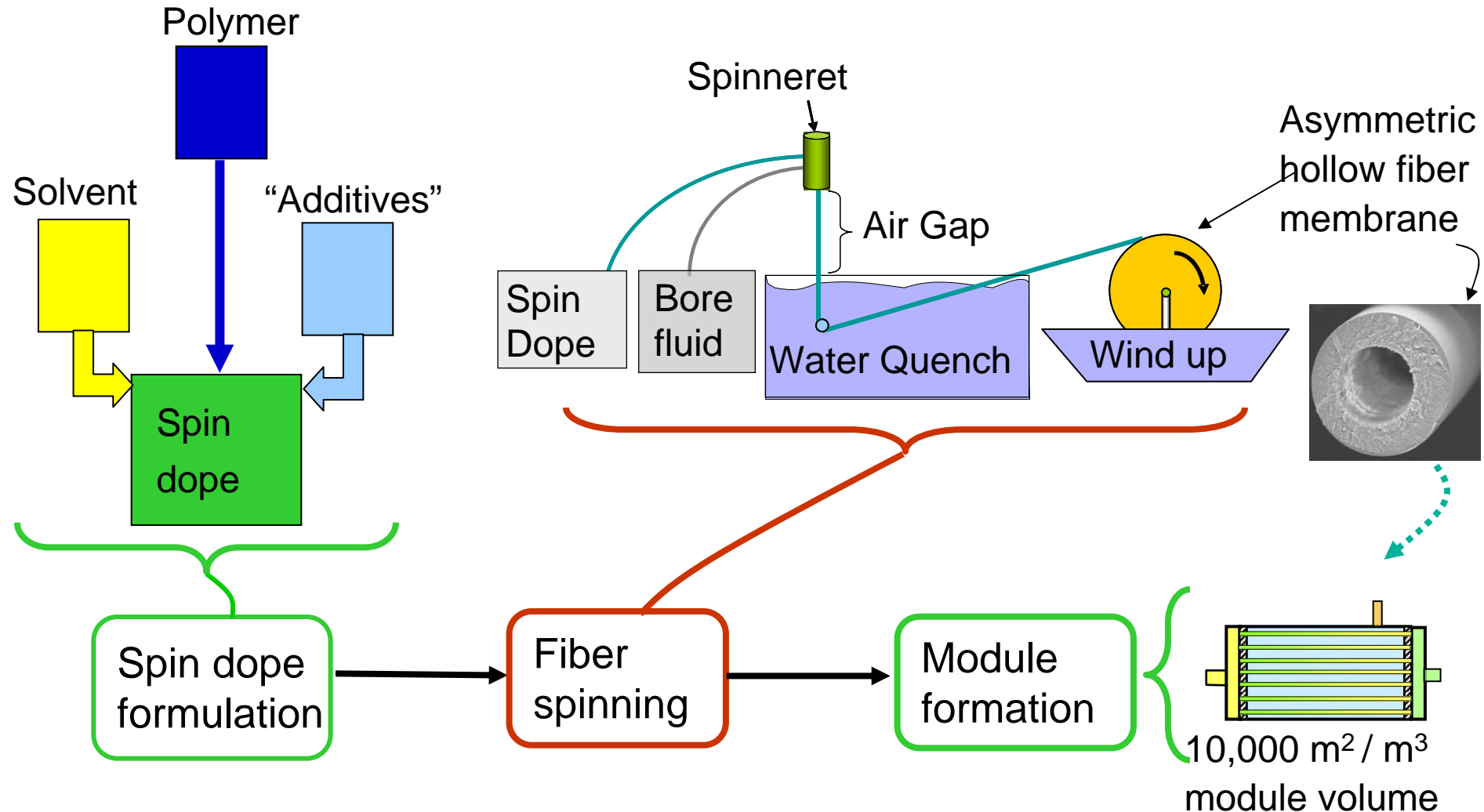


- C<sub>3</sub>H<sub>6</sub> Production: 84 billion lbs/yr
- 8 -10 new world scale units @ 0.5 billion lb/yr via cryo-distillation units (~\$50 Million ea.)

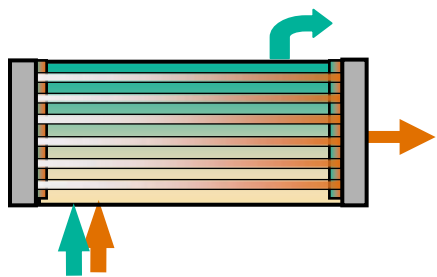


- Membranes can slash separation energy costs for such cases--KAUST can lead the world to processes with lower energy use by pioneering such advanced membrane technology based on new types of membranes !

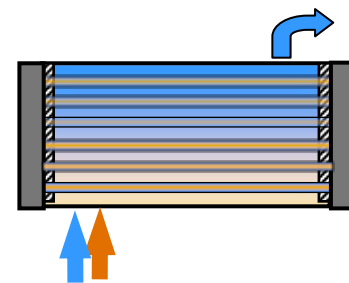
# Hollow fiber membranes—an integrated technology platform that can be developed at KAUST



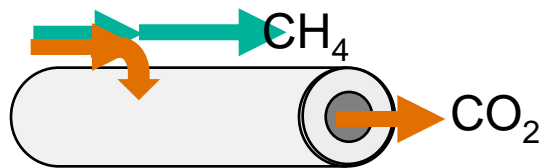
# Membrane know-how can enable novel concepts in advanced sorbents as well



Modules with millions of fibers give huge contact areas, so fiber technology is “enabling” for both membranes & sorbents!

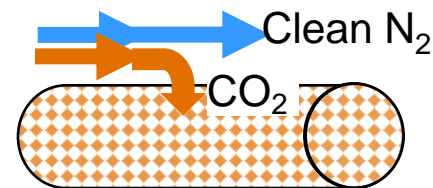


Natural gas feed

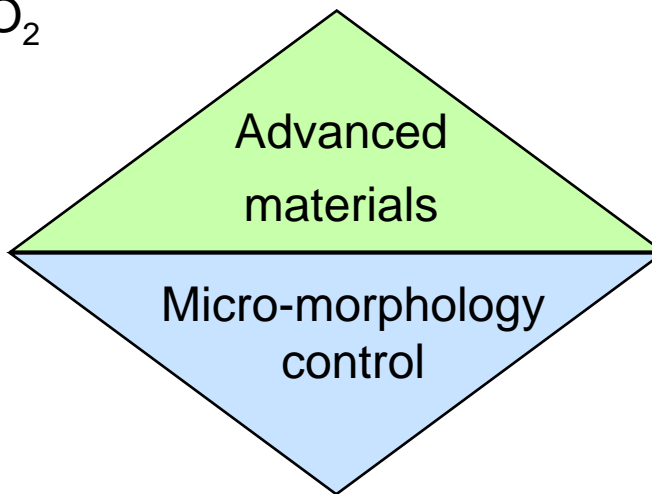


Hollow Fiber Membrane

Flue gas feed



Fiber Sorbent



# Expedited emergence of a membrane center of excellence at KAUST



My experience in membranes will assist the Kingdom in reaching this goal through the KAUST Investigator program by:

- Assistance in faculty recruiting for the KAUST Membrane and Desalination Centers
- Mentoring and transfer of the art and science of membranes during 3-wks/yr personal on-site visits to KAUST
- Offering input on specialty low energy separation courses
- Video conferences with my USA group on equipment topics and membrane formation & characterization techniques
- Collaborative development of the new area of novel fiber sorbents— a mutual adventure and learning experience!