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Resource Recovery and Environmental Protection in Wyoming's Greater Green River Basin Using Selective Nanostructured Membranes

DE-FE0031855

Dr. Jonathan Brant, Dr. Stefan Heinz (UW)
Mr. Thomas England (Triton)
Mr. Vaughn Jones (H2O Systems)

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Task 1
Project Management and Planning

Jonathan Brant (UW)

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Project Team

2 Faculty at UW

- Jonathan Brant: Tasks 1-3
- Stefan Heinz: Task 2

H2O Systems Team

- Vaughn Jones: Tasks 2-3
- Aaron Worlie: Task 3

Triton Water Midstream Team

- Thomas England: Task 3

MS/PhD Students at UW

- Seyed Mahdi: Tasks 2-3
- Pius Jjagwe: Task 2
- To be hired: Task 2

Other UW Research Team Members

- Thomas Johnson: Task 3

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Project Goals and Objectives

This project will develop a working prototype of a two-part affinity based membrane separation process for recovering hydrocarbons, and separating particulates and organics, from produced water originating from the Greater Green River Basin in Wyoming. To this end we will:

i. Synthesize superhydrophobic/oleophilic and superhydrophilic/oleophobic membranes to achieve high flux/selectivity for BTEX/oil and water filtration while being resistant to fouling from particulates and organics representative of GGRB produced waters, respectively.

ii. Design and manufacture membrane spacers and channel geometries optimized for phase separation/recovery in spiral wound membrane element configurations.

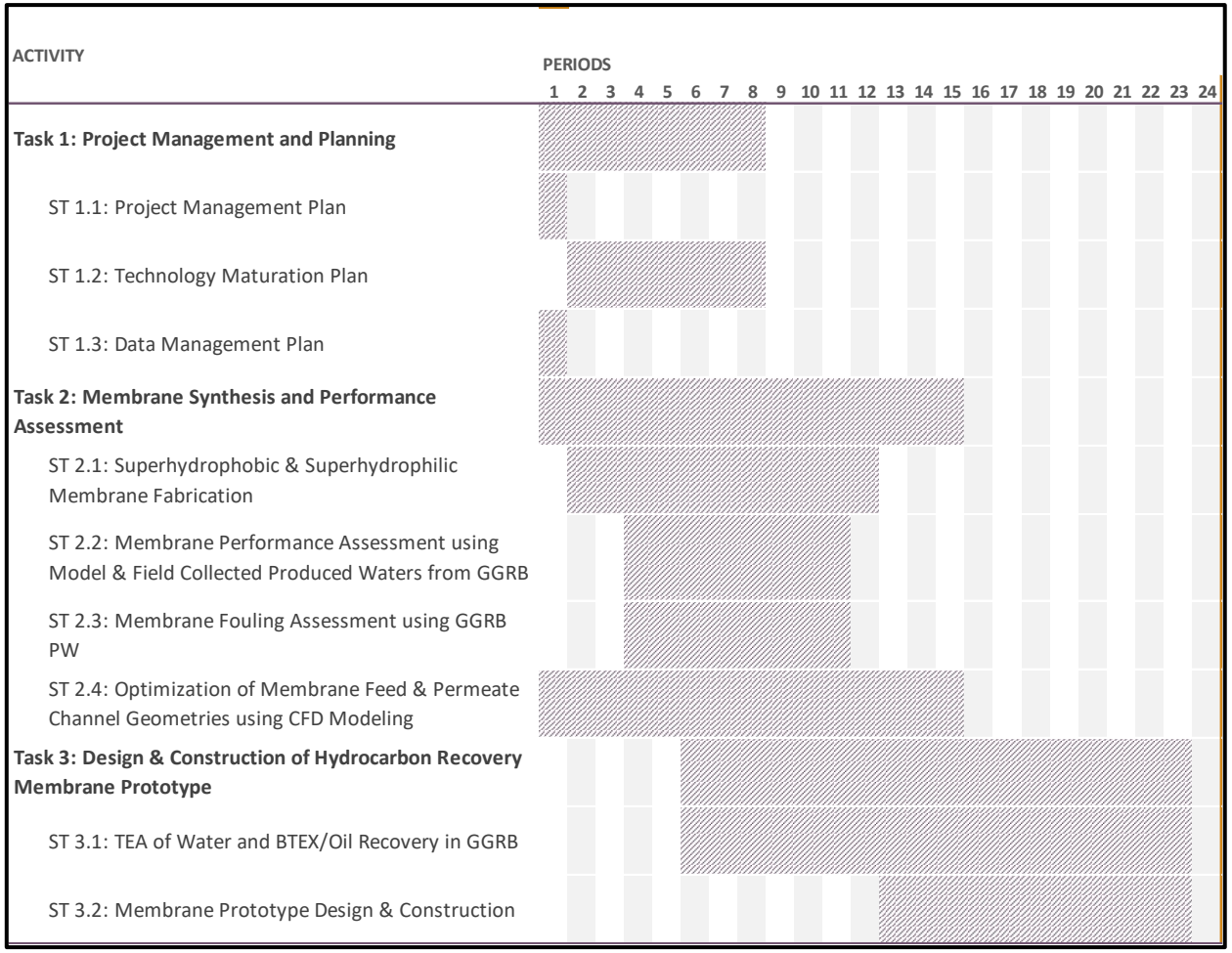
iii. Execute a techno economic assessment (TEA) of the implementation of the proposed membrane process in the GGRB to include economic benefits from resource (BTEX/oil) recovery, water savings, and reduced treatment costs.

iv. Deliver two membrane prototype modules for BTEX/oil recovery and water filtration.

Project Schedule

Key Dates:

- Project Start – Jan 1, 2020
- Project End – Dec 31, 2021



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Project Budget

	Budget Period 1		Budget Period 2		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	**Cost Share**
Applicant	$746,743	$0	$459,520	$0	$1,206,263	**$0**
H2O Systems	$6,700	$155,000	$6,400	$85,500	$13,100	**$240,500**
Triton Water	$0	$40,000	$0	$19,500	$0	**$59,500**
Total ($)	**$753,443**	**$195,000**	**$465,920**	**$105,000**	**$1,219,363**	**$300,000**

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Anticipated Products & Deliverables

Products

- Project Management Plan
- Data Management Plan
- Final Project Report

View from the Outside *– Knowledge generated on relating membrane properties to selective phase permeation will advance the development of "smart" membranes for targeted resource recovery.*

Deliverables

- Superhydrophobic/oleophilic membrane prototype
- Superhydrophilic/oleophobic membrane prototype
- Produced water characterization results for GGRB
- TEA for BTEX/oil/water recovery process in GGRB

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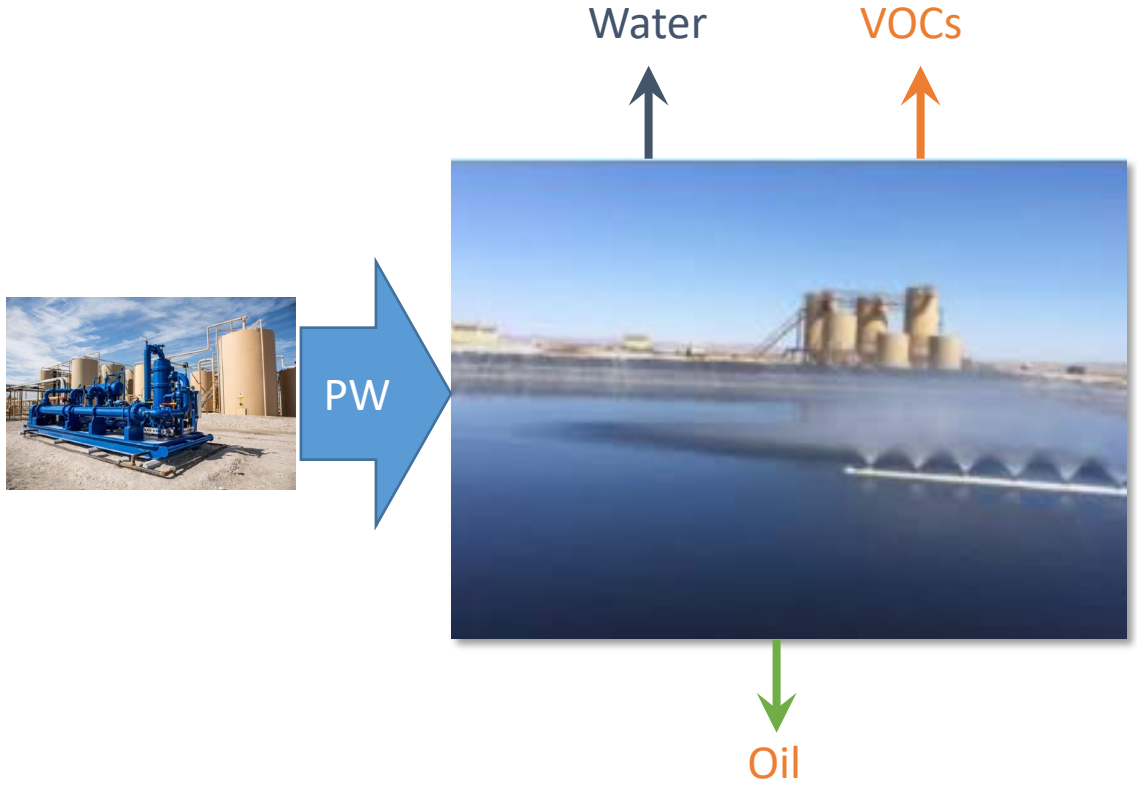
Research Challenges & Knowledge Gaps



- Hydrocarbon recovery via separators is incomplete leaving VOCs/free oils to persist in PWs moved to pits
  - VOC concentrations in GGRB ~ 0.06 to 5.1 lbs/bbl
- VOC emissions are problematic from an environmental perspective & BTEX/oil represents lost revenue

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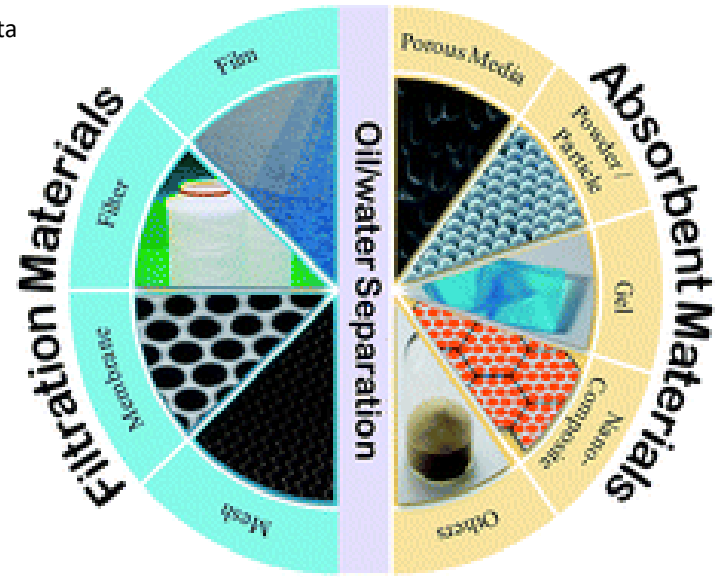
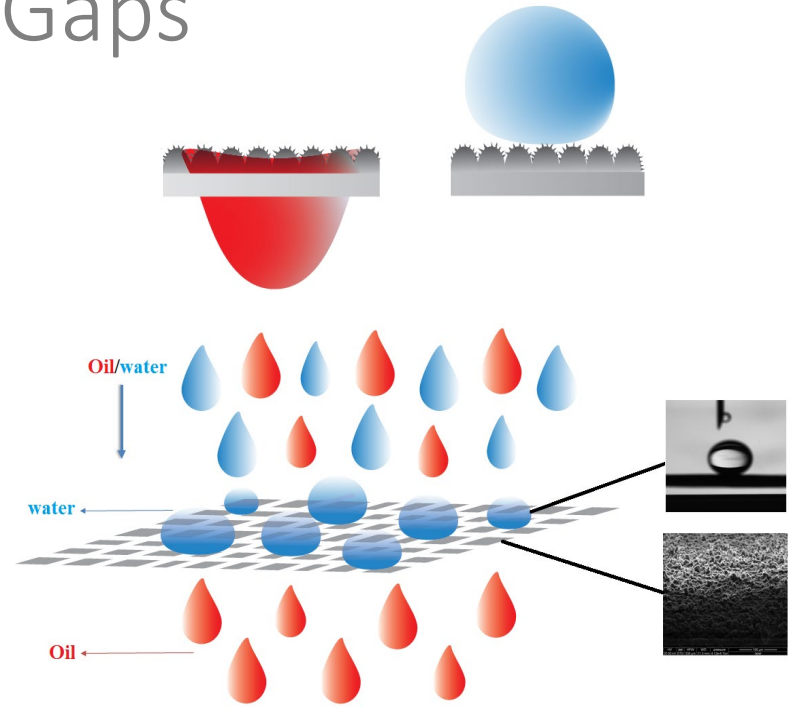
Research Challenges & Knowledge Gaps

***Image Credit**: Gupta et al. 2017



Conventional separations plagued by inefficiencies related to non-selectivity and inability to target dispersed fractions.



Development of "smart" membrane materials reduces fouling and achieves high selectivity for target phase.

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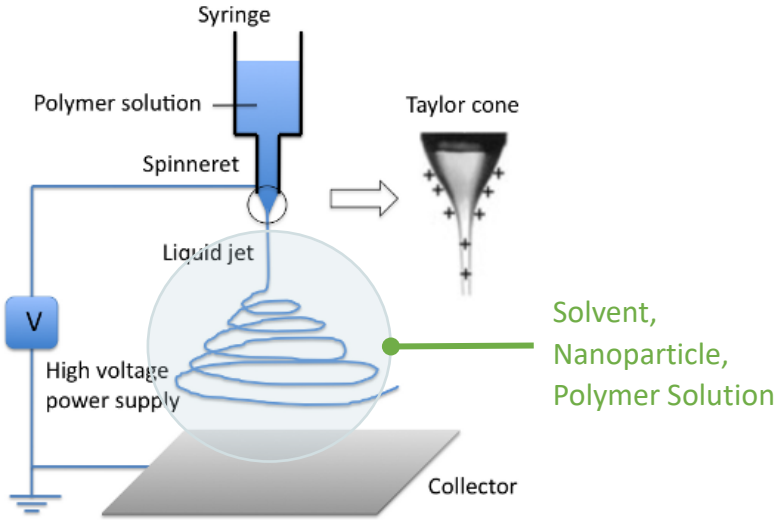
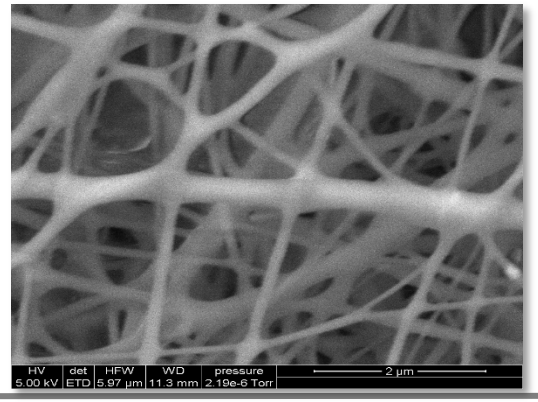
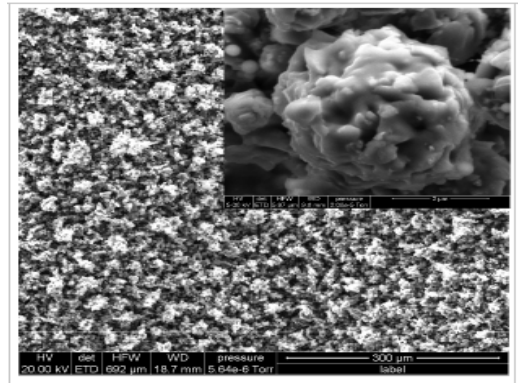
Research Challenges & Knowledge Gaps



Challenge – creating membrane modules / elements using electrospun membranes while optimizing process hydraulics and maintaining separation efficiency

Using interfacial chemistry, the selectivity of the membrane is tailored through selection of appropriate nano-surface coating(s).





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Task 2
Membrane Synthesis and Performance Assessment

Jonathan Brant (UW)

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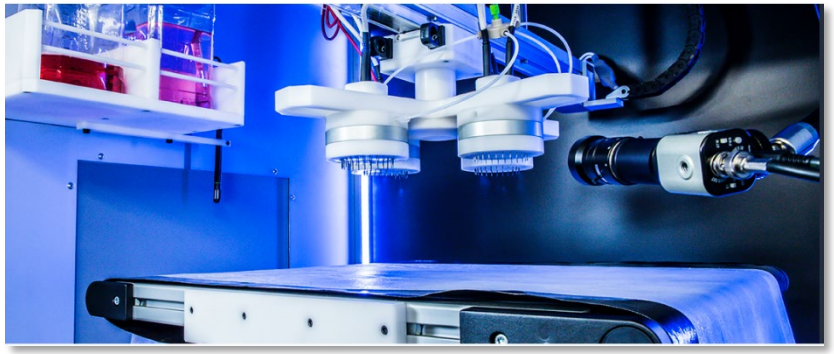
Membrane Fabrication

- Superhydrophobic membranes made coating PVDF nanofibers w/ nano-carbon black
  - Spinning/spraying conditions manipulated to optimize fiber size → liquid entry pressure
  - Surface coatings explored for enhancing non-aqueous phase adhesion to fibers (enhanced permeation)
- Superhydrophilic membranes made using polyacrylonitrile
- Synthesis conditions optimized for roll-to-roll production required for prototype construction



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Membrane Performance Testing

- Performance evaluated using model and field collected PW samples from the GGRB
  - Performance = flux, selectivity (rejection), and fouling (performance degradation w/ time)
- Water samples analyzed for TDS, particulates, BTEX, organics, and O&G
- Feed/permeate spacer design optimized for mass transfer in respective channels
  - Spacer design optimized through CFD modelling
  - Spacer construction done using 3D printing

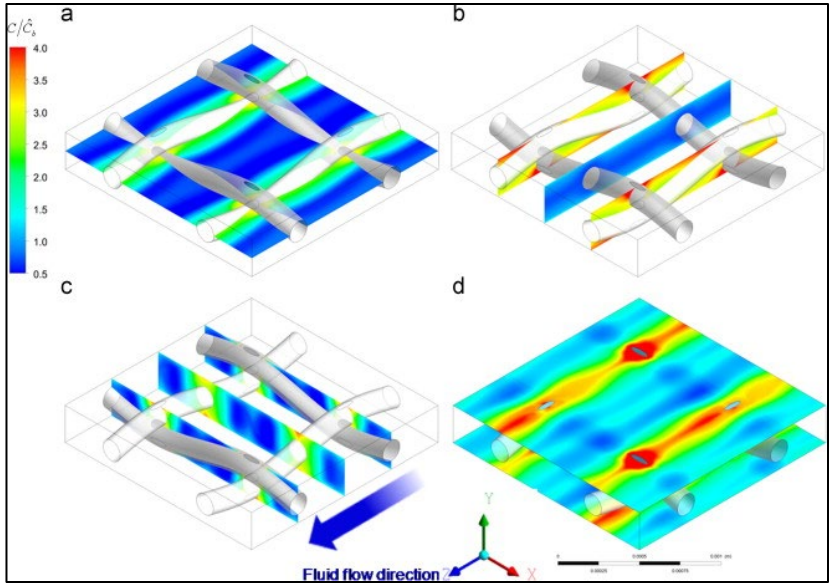

Image Credit: Gurreri et al. 2014.

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Task 3
Design and Construction of Hydrocarbon Recovery Membrane Prototype

Thomas England (Triton)

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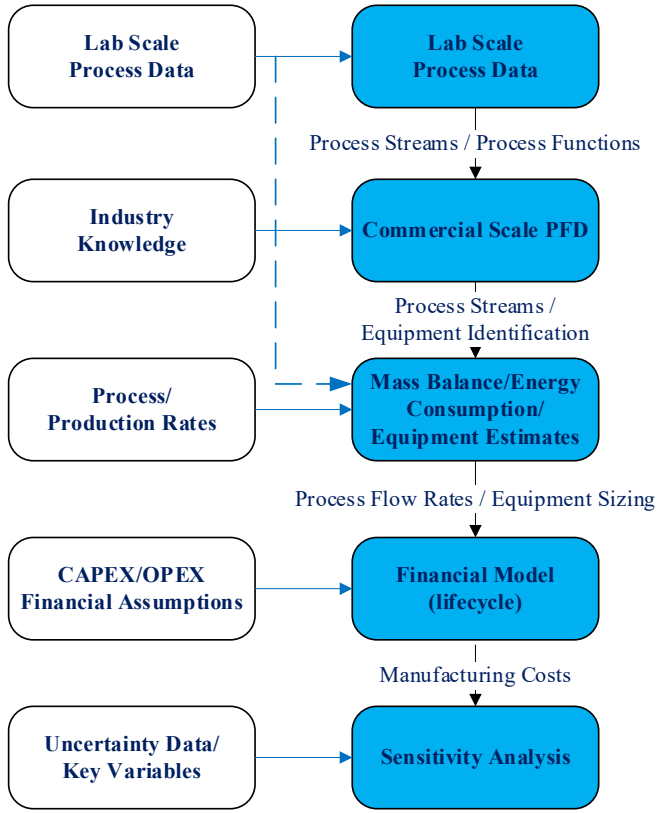
TEA of Water and BTEX/Oil Recovery in GGRB

- Input data (PW WQ, existing PW management costs) collected from existing management facilities in the GGRB (operated by H2O & Triton)
- Contemplate both economic profitability and market analysis

Membrane Prototype Design and Construction

- Spiral wound configuration w/ approximate dimensions of 2.5×21 in
- Housings are commercially available FRP
- Channel dimensions and spacers optimized based on findings from Task 2



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Project Milestones & Success Criteria

Task/ Subtask	Milestone Title & Description	Planned Completion Date	Verification Method
1.1	M1 - Project Management Plan	01/30/2020	PMP is received by the DOE Project Manager
1.2	M2 – Technology Maturation Plan (TMP)	09/01/2020	TMP is received by the DOE Project Manager
1.3	M3 – Data Management Plan (DMP)	01/30/2020	DMP is received by the DOE Project Manager
2.2, 2.3, 3.1	M4 – Water samples collected & characterized from 4 distinct stations in GGRB (70% of total sites)	09/01/2020	UW summarizes and reports PW WQ data to H2O/Triton for TEA & use in initial phase membrane performance analyses
	M5 – Continuation Application	09/01/2020	Continuation Application is received by the DOE Project Manager
2.1	M6 – Design of superhydrophobic & superhydrophilic membranes is complete	12/31/2020	UW reports bench-scale performance and characterization analysis data on membranes (final design and iterations) to match with prototype requirements
2.4	M7 – Completion of CFD modelling for membrane spacers & channel height	04/01/21	Dimensions (AUTOCAD files) and geometry of spacers/flow channel reported to PI and Triton
3.1	M8 – TEA of BTEX/oil recovery process complete	12/31/2021	H2O/Triton reports TEA to UW/DOE
3.2	M9 – Membrane prototype design and construction complete	12/31/2021	UW presents prototype design and performance specs to DOE Project Manager

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Current Activities

- Submitted PMP and DMP
- RFP submitted for bidding for the pilot-scale electrospinning/spraying system
- Working with H2O/Triton to finalize PW sampling locations in GGRB
- Continuing work on optimizing electrospinning/spraying conditions for hydrophobic/hydrophilic membranes
- Initiated CFD modelling construct for feed channel spacers