



Techno-economic analysis and life cycle assessment of manufacturing a cellulose nanocrystal-based hybrid membrane

Research Team

Naveenkumar Rajendiran - University of Wisconsin / Forest Products Laboratory, Madison, WI, USA

Troy Runge – University of Wisconsin, Madison, WI, USA

Rick Bergman – Forest Products Laboratory, Madison, WI, USA

Nepal Prakash – Forest Products Laboratory, Madison, WI, USA

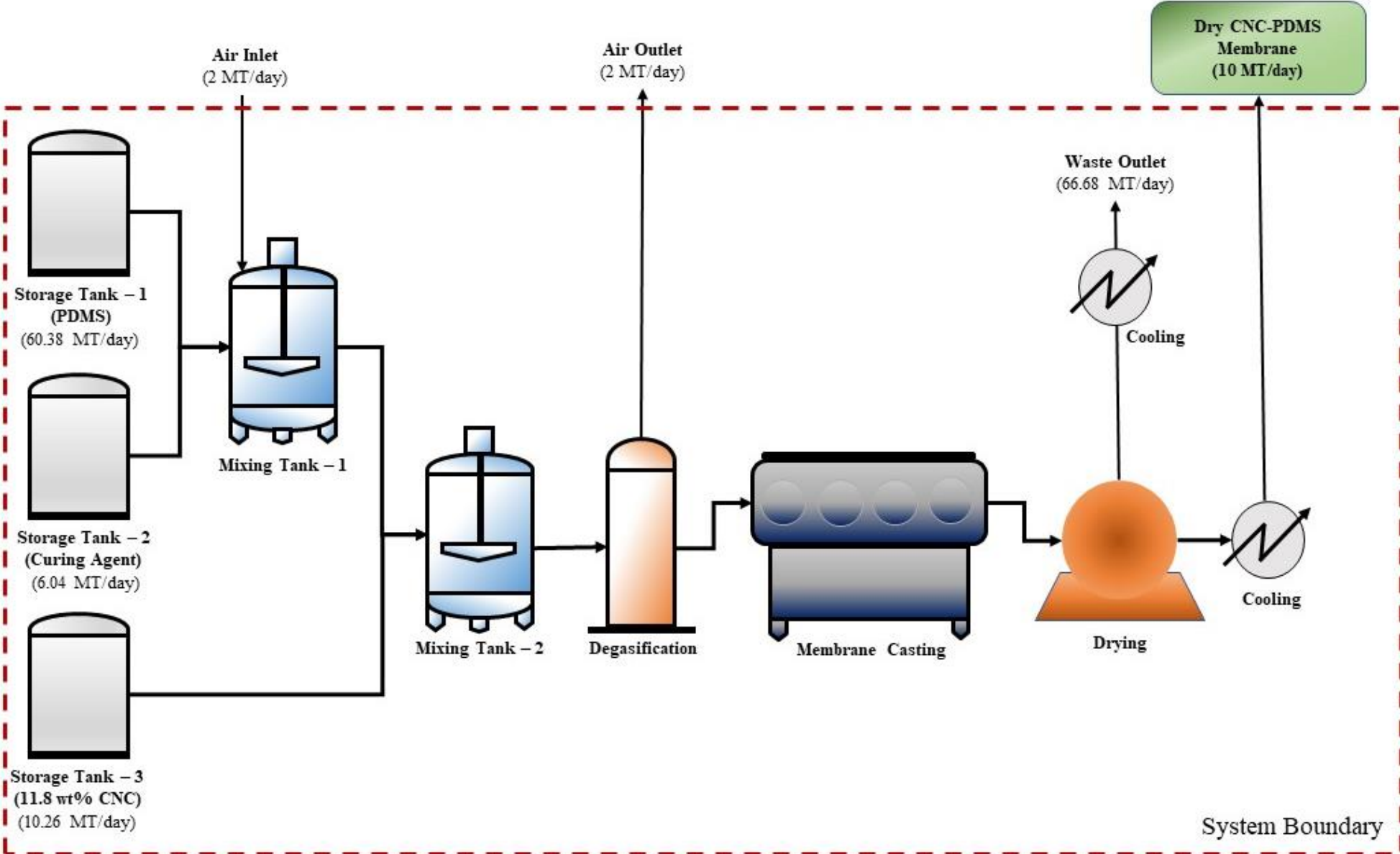
Nasim Alikhani – University of Maine, Orono, ME, USA

Ling Li – University of Maine, Orono, ME, USA

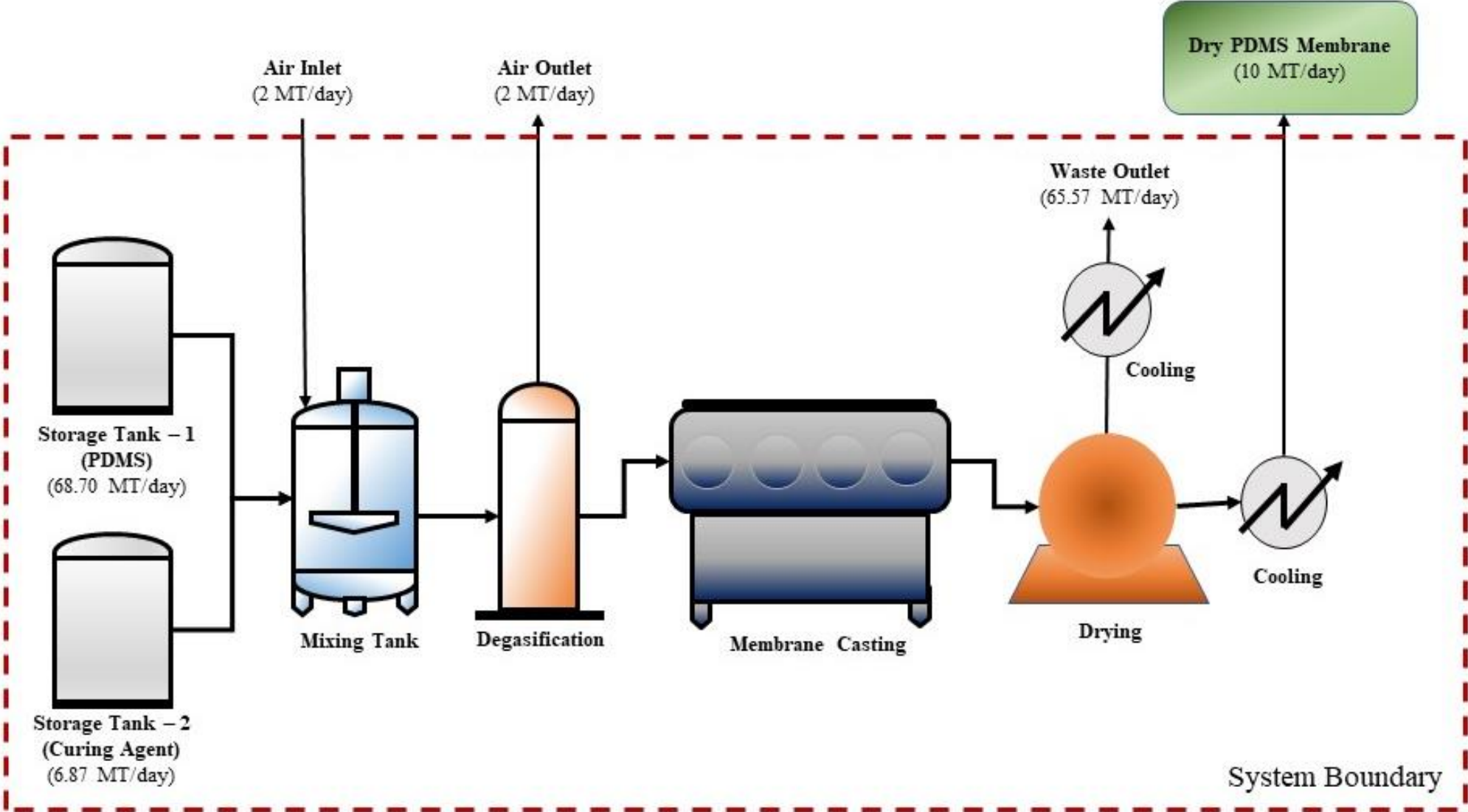
Shane R. O'Neill – University of Maine, Orono, ME, USA

Jinwu Wang – University of Maine, Orono, ME, USA

CNC-PDMS membrane production process model

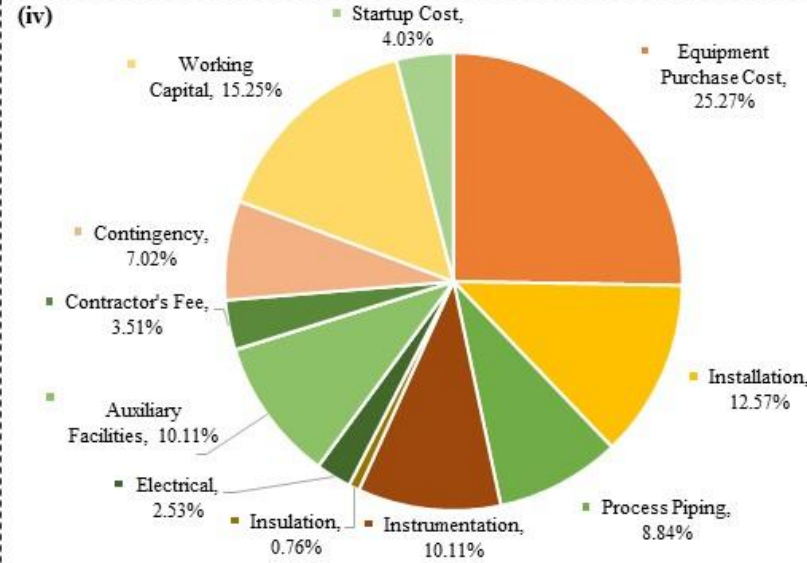
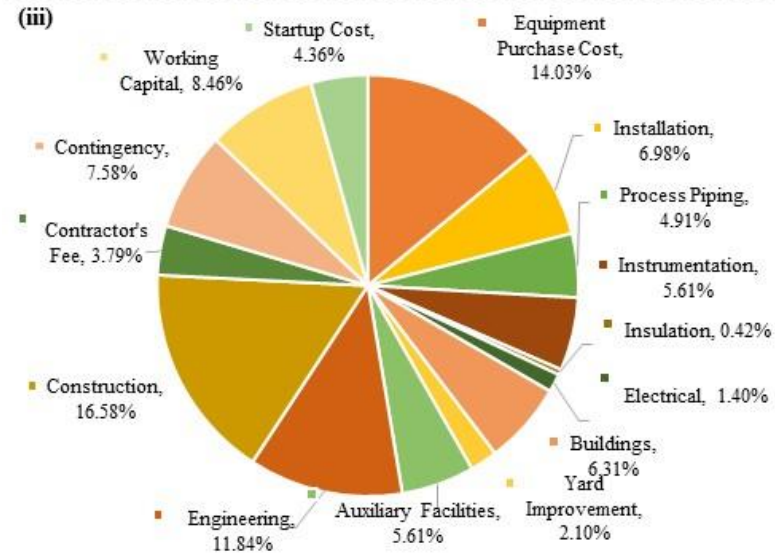
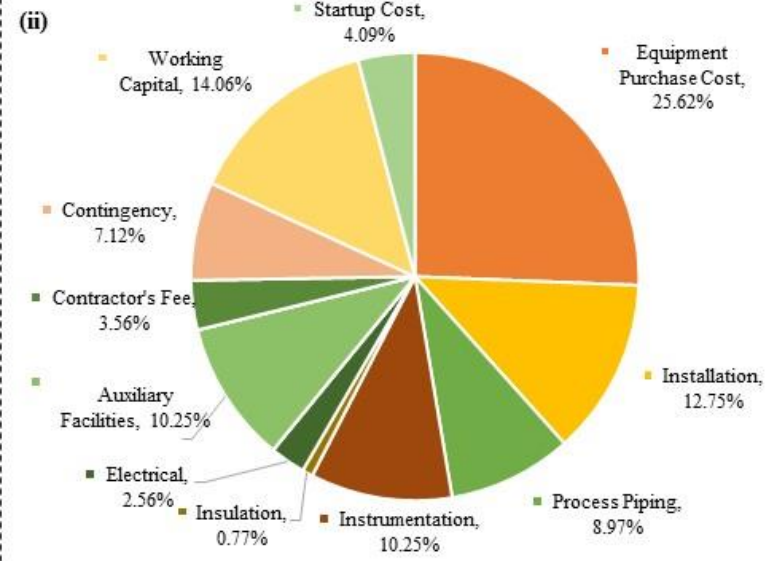
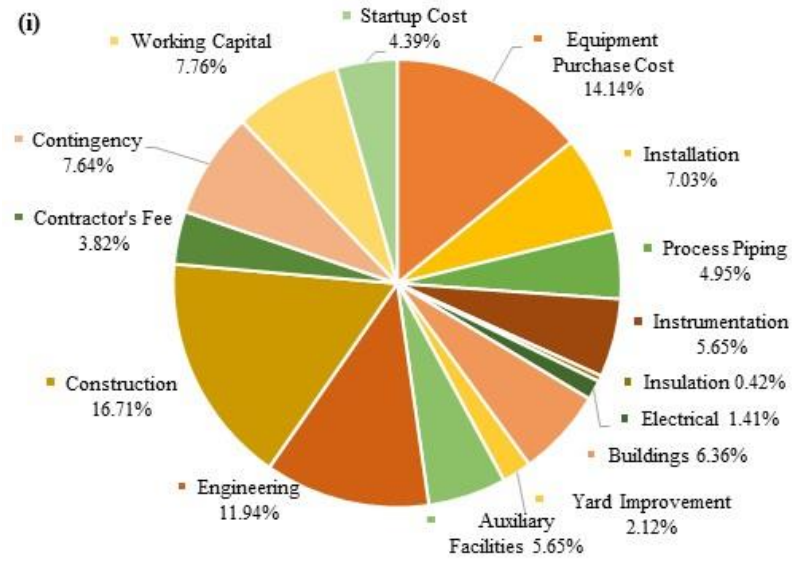


PDMS membrane production process model



Capital Investment

GREENFIELD

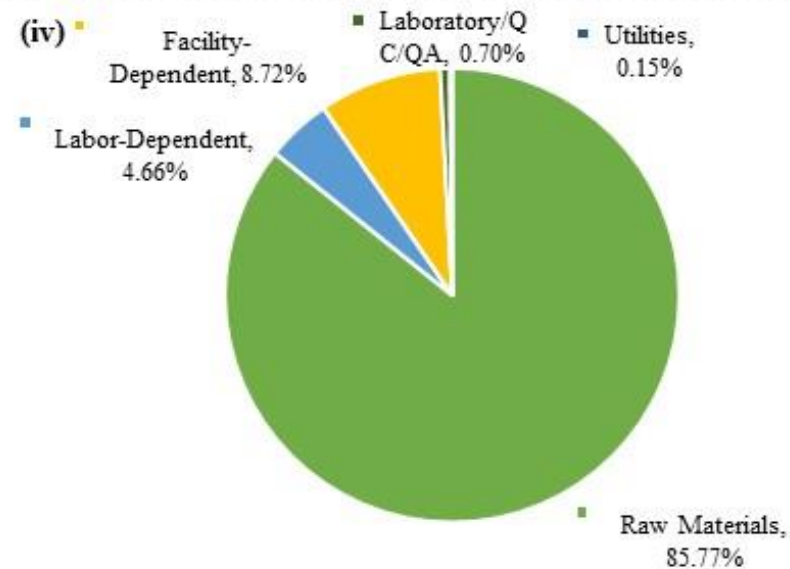
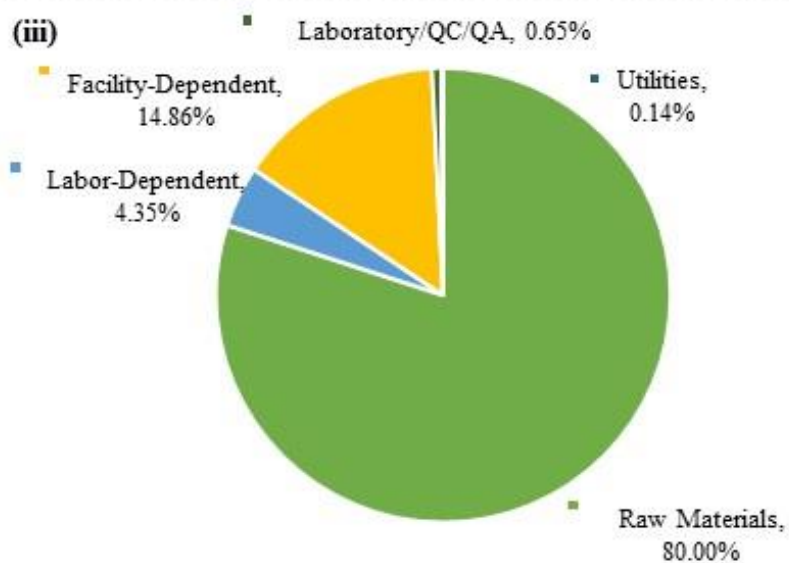
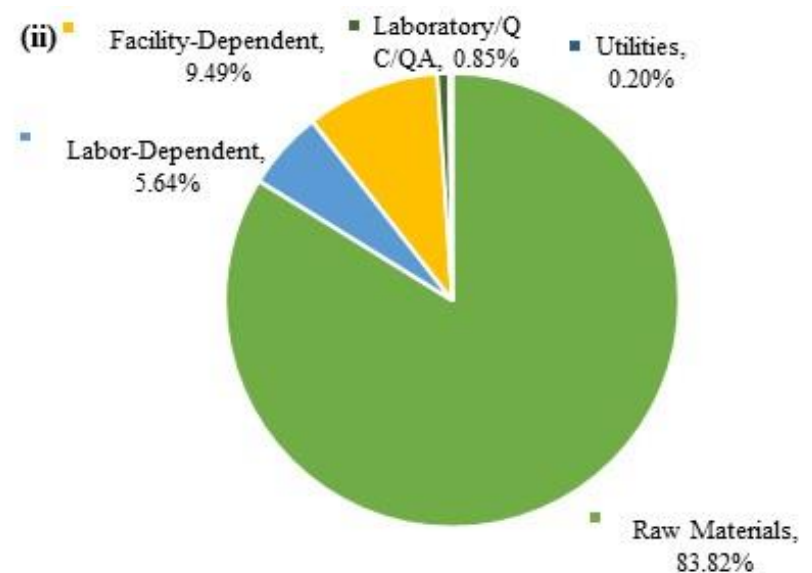
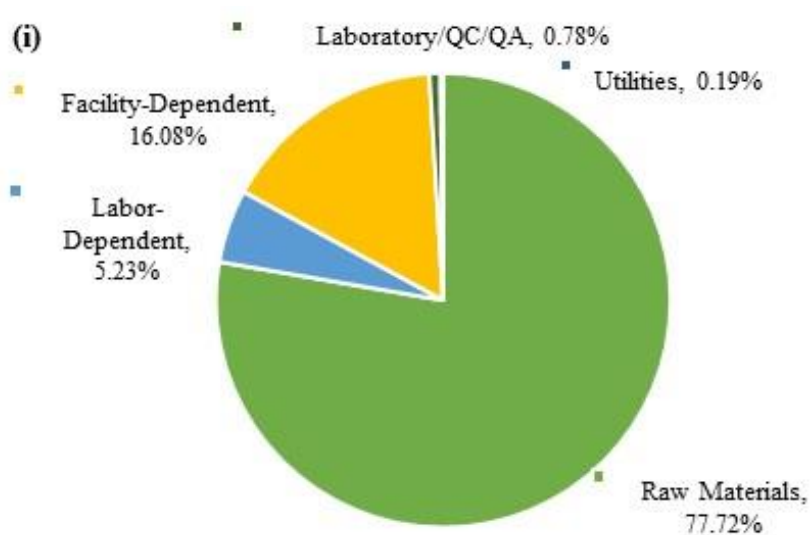


EXPANDING IN AN EXISTING PLANT

(i) Cellulose nanocrystal/polydimethylsiloxane membrane preparation (greenfield) - \$135,564,000 (ii) cellulose nanocrystal/polydimethylsiloxane membrane preparation (expanding in an existing plant) - \$74,786,000, (iii) polydimethylsiloxane membrane preparation (greenfield) – \$135,000,000, and (iv) polydimethylsiloxane membrane preparation (expanding in an existing plant) – \$74,941,000

Annual Operating Cost

GREENFIELD



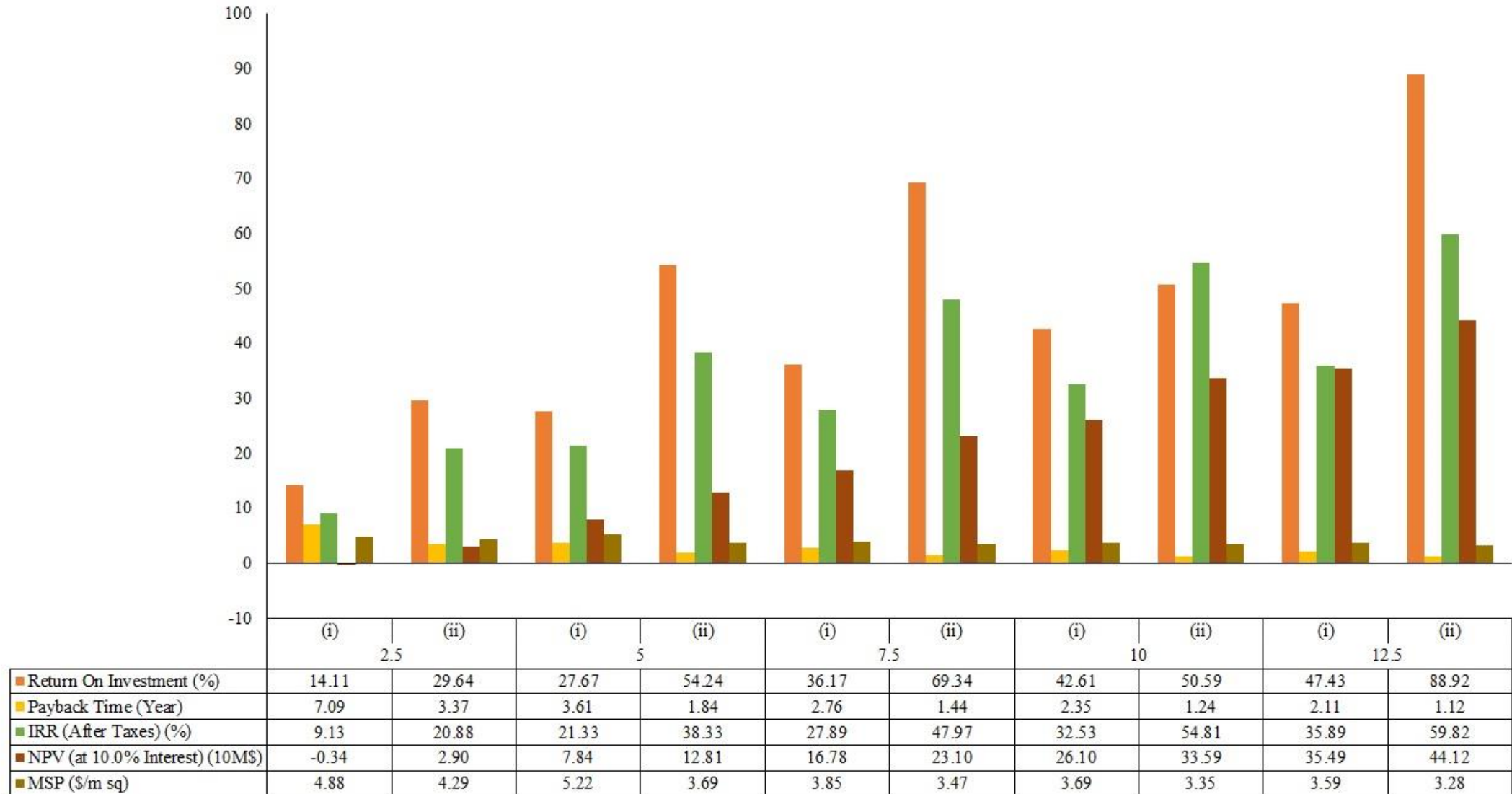
EXPANDING IN AN EXISTING PLANT

(i) Cellulose nanocrystal/polydimethylsiloxane membrane preparation (greenfield) - \$139,119,000 (ii) cellulose nanocrystal/polydimethylsiloxane membrane preparation (expanding in an existing plant) - \$128,989,000, (iii) polydimethylsiloxane membrane preparation (greenfield) - \$148,785,000 and (iv) polydimethylsiloxane membrane preparation (expanding in an existing plant) - \$138,775,000

Economic summary of the membrane production process

Description	Cellulose nanocrystal/polydimethylsiloxane (Greenfield)	Cellulose nanocrystal/polydimethylsiloxane (expanding in an existing plant)	Polydimethylsiloxane (Greenfield)	Polydimethylsiloxane (expanding in an existing plant)
Capital Investment (\$)	135,564,000.00	74,786,000.00	135,000,000.00	74,941,000.00
Operating Cost (\$/yr)	139,119,000.00	128,989,000.00	148,785,000.00	138,775,000.00
Revenues (\$/yr)	197,921,000.00	197,921,000.00	197,921,000.00	197,921,000.00
Cost Basis Annual Rate (kg/yr)	3,298,680.00	3,298,680.00	3,298,680.00	3,298,680.00
Net Unit Production Cost (\$/kg)	42.17	39.10	45.10	42.07
Unit Production Revenue (\$/kg)	60.00	60.00	60.00	60.00
Gross Margin (%)	29.71	34.83	24.83	29.88
Return On Investment (%)	42.61	80.59	37.04	70.02
Payback Time (Yr)	2.35	1.24	2.70	1.43
IRR (After Taxes) (%)	32.53	54.81	28.87	49.44
NPV (at 10.0% Interest) (\$)	260,994,000.00	335,868,000.00	209,492,000.00	314,361,000.00
MSP of Membrane (\$/m ²)	3.68	3.35	3.93	3.60

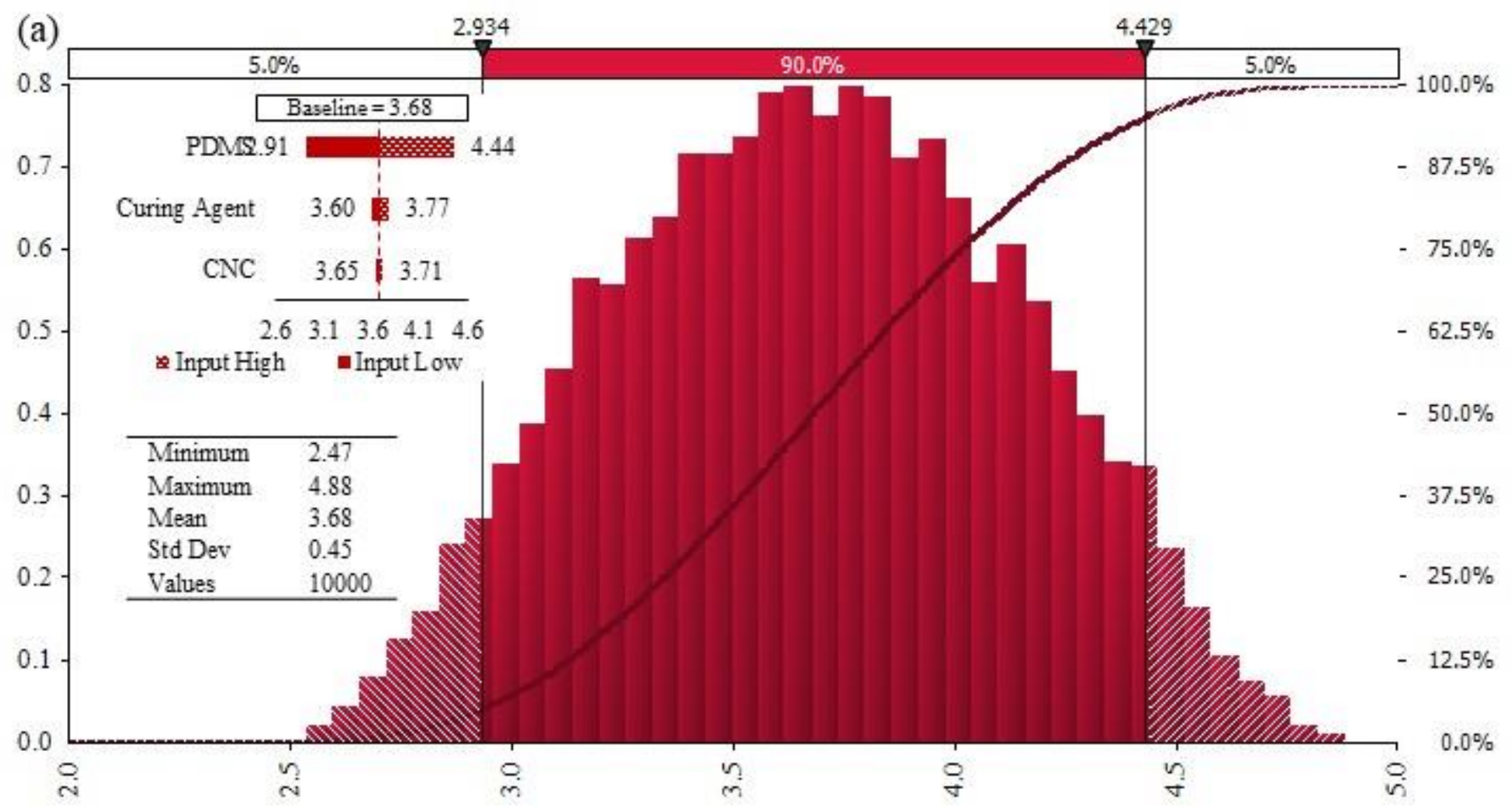
Estimated effects on the profitability factors and minimum selling price of changes on plant capacity



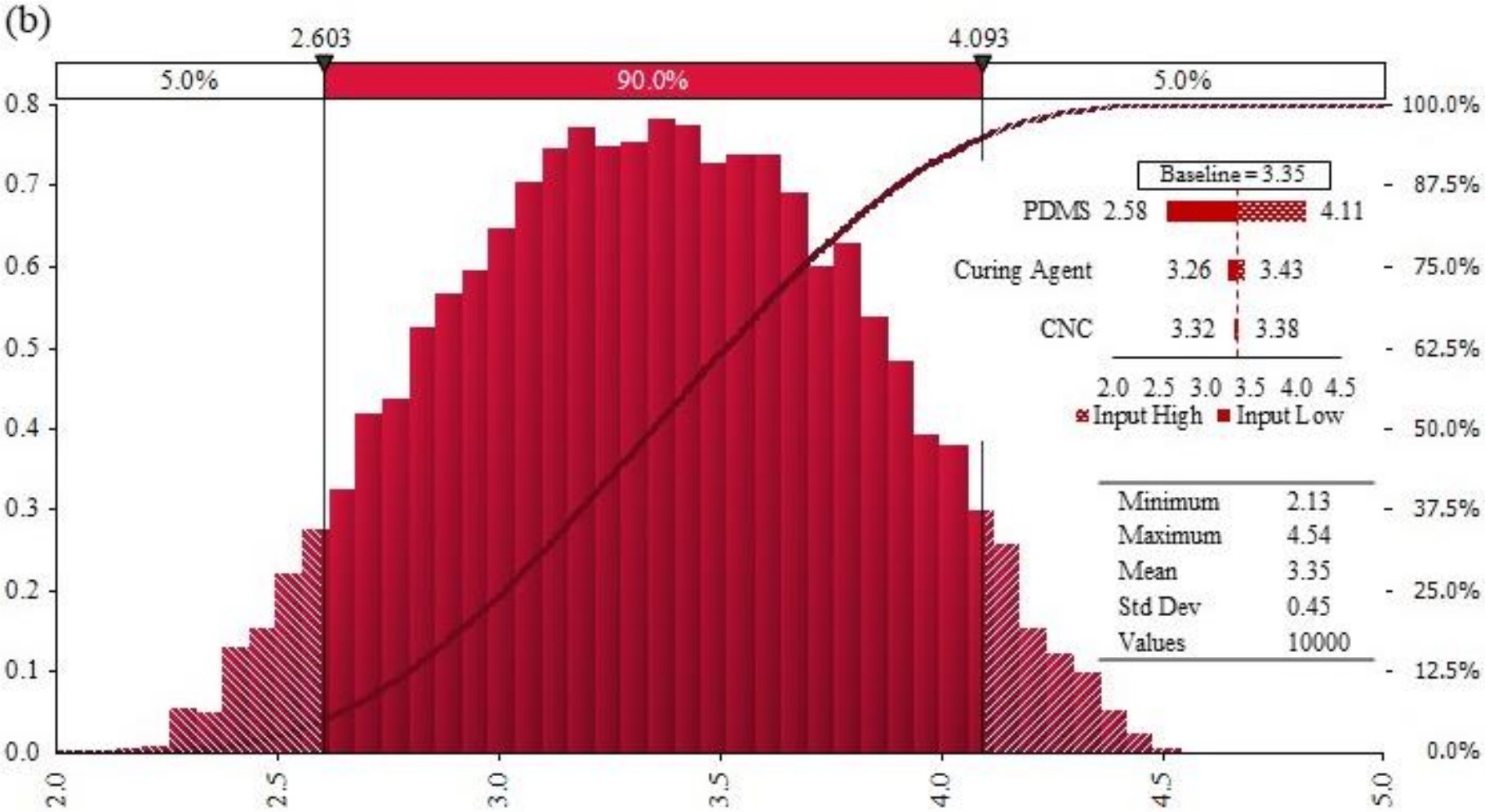
(i) Cellulose nanocrystal/polydimethylsiloxane membrane preparation (greenfield)

(ii) Cellulose nanocrystal/polydimethylsiloxane membrane preparation (expanding in an existing plant)

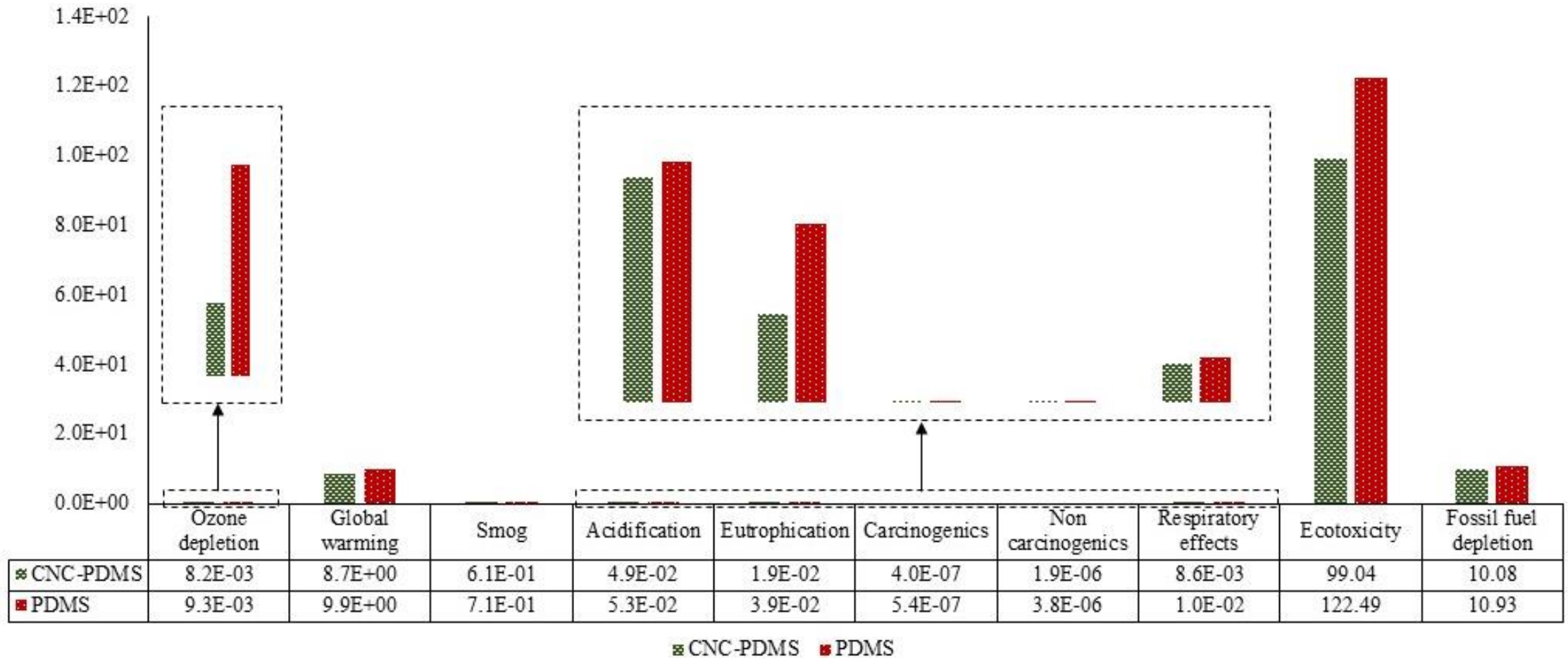
Minimum selling price of cellulose nanocrystal/polydimethylsiloxane (Greenfield)



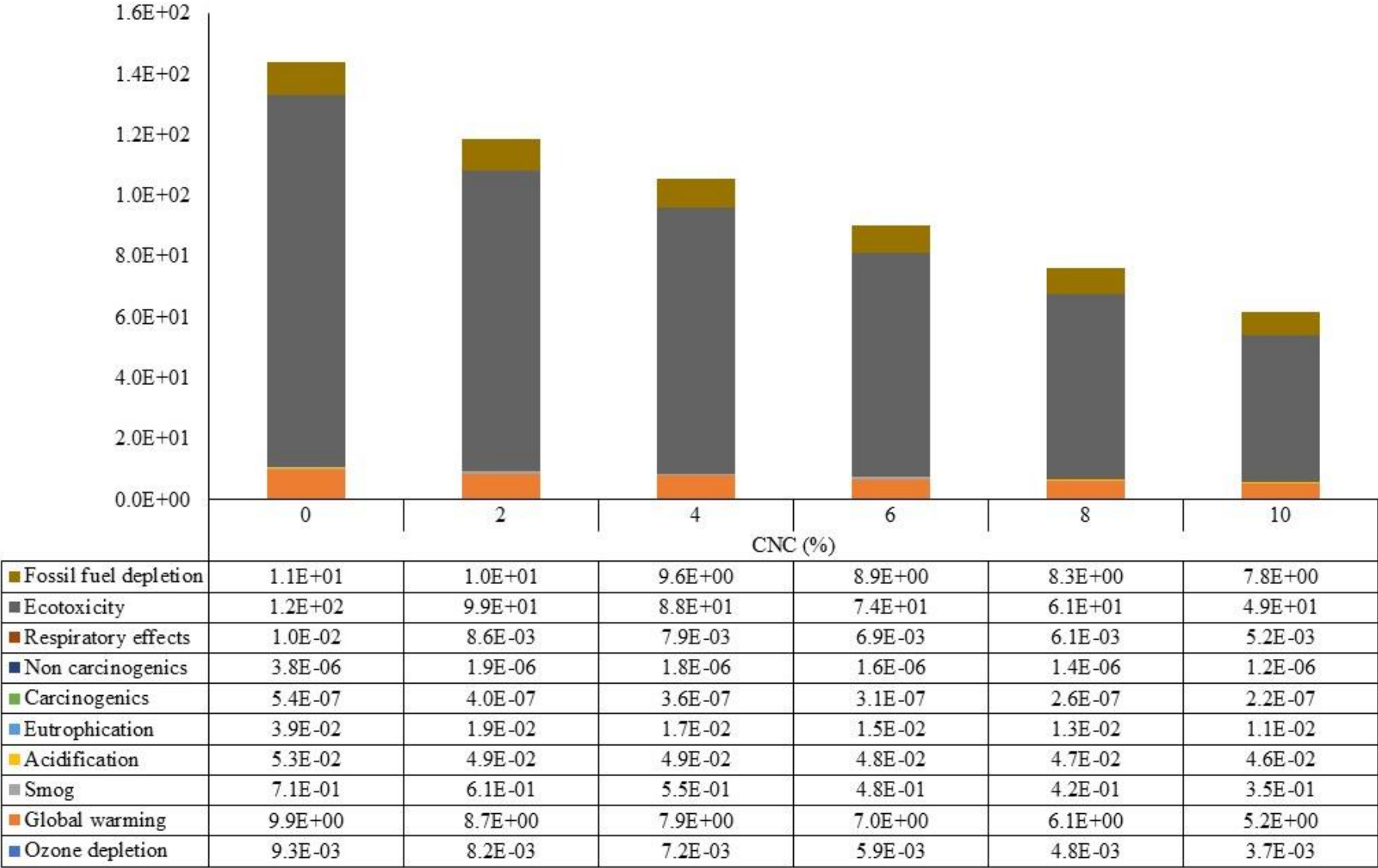
Minimum selling price of cellulose nanocrystal/polydimethylsiloxane (Expanding in an existing plant)



Cradle-to-gate life cycle impacts of cellulose nanocrystal/polydimethylsiloxane and polydimethylsiloxane membranes



Cradle-to-gate environmental impacts of increasing the percent of CNC on PDMS membrane,



Publication

R. Naveenkumar*, R. Troy, B. Richard, N. Prakash, A. Nasim, L. Ling, O. Shane, W. Jinwu, Techno-economic analysis and life cycle assessment of manufacturing a cellulose nanocrystal-based hybrid membrane. **Separation and Purification Technology**, Vol. 40 (2023) 503-515.

Funded by

P3Nano – Advancing Commercialization of Cellulosic Nanomaterials

United States Endowment for Forestry and Communities

Thank You