



Ccents

**Circular Economy Network+
in Transportation Systems**

Wastewater derived ammonia: *Contaminant to carbon free transportation fuel*



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Rationale

1943 – Belgium; buses run on ammonia adapted internal combustion engine



2018 – Toyota produce direct ammonia to hydrogen fuel cell vehicles



2024 – Viking Energy – Direct Ammonia Fuel Cell Vessel




Ammonia



10 billion litres of wastewater per day, with ammonia concentration $\sim 40\text{gNH}_3\text{ m}^{-3}$

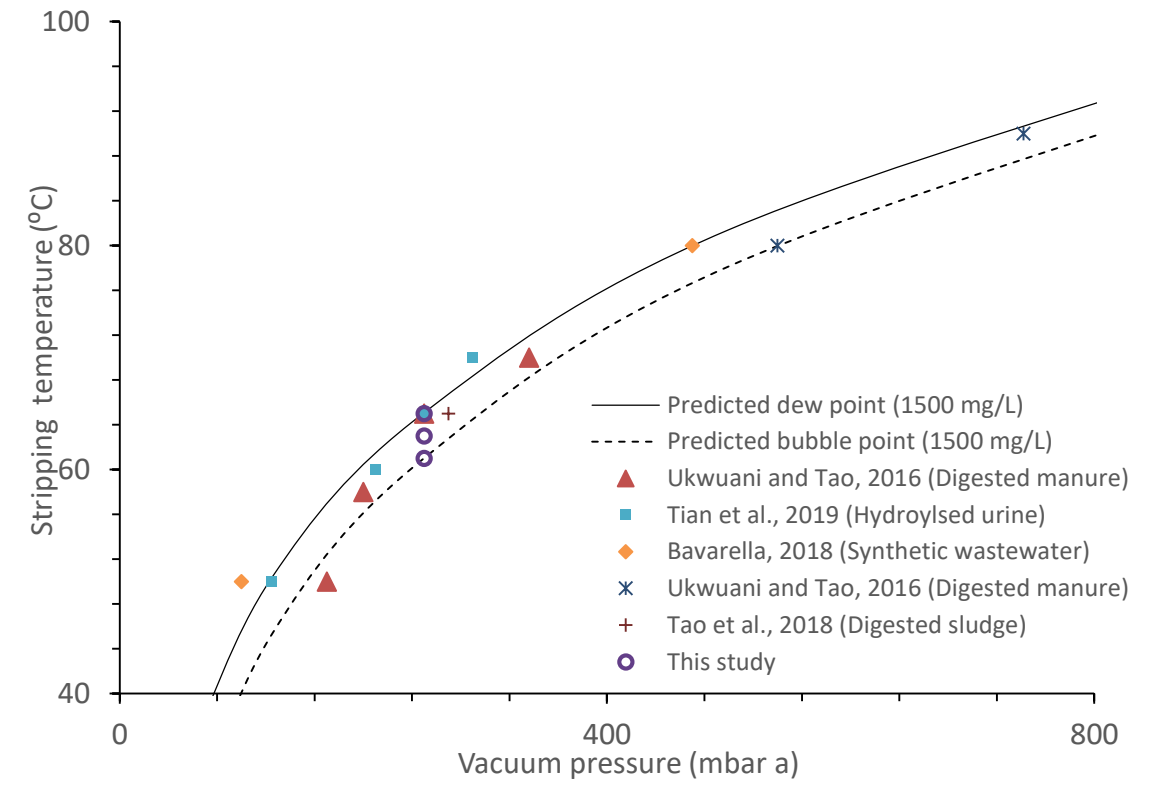
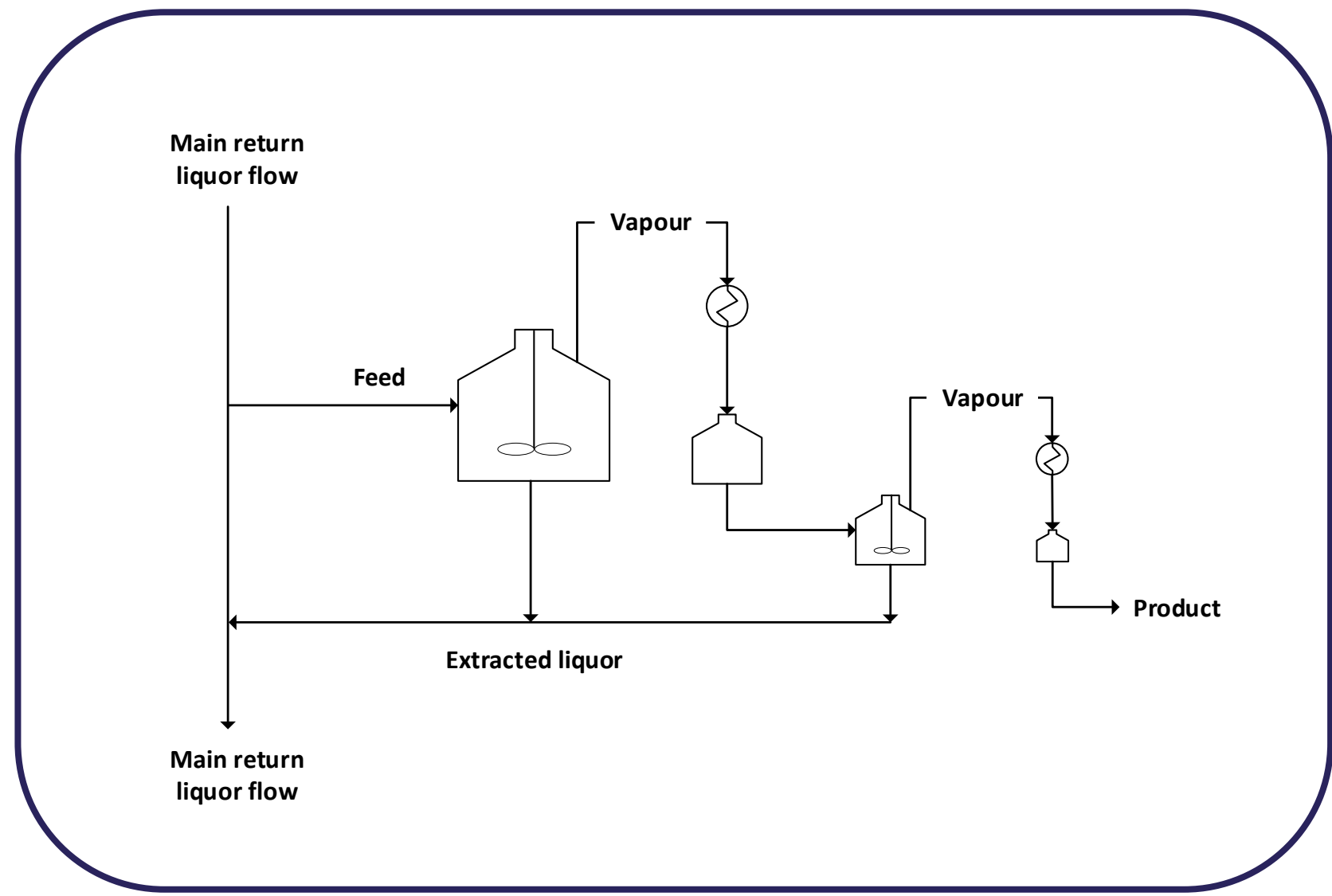


0.18 kWh m^{-3} energy input to treat $\sim 1.8\text{ GWh per y}$

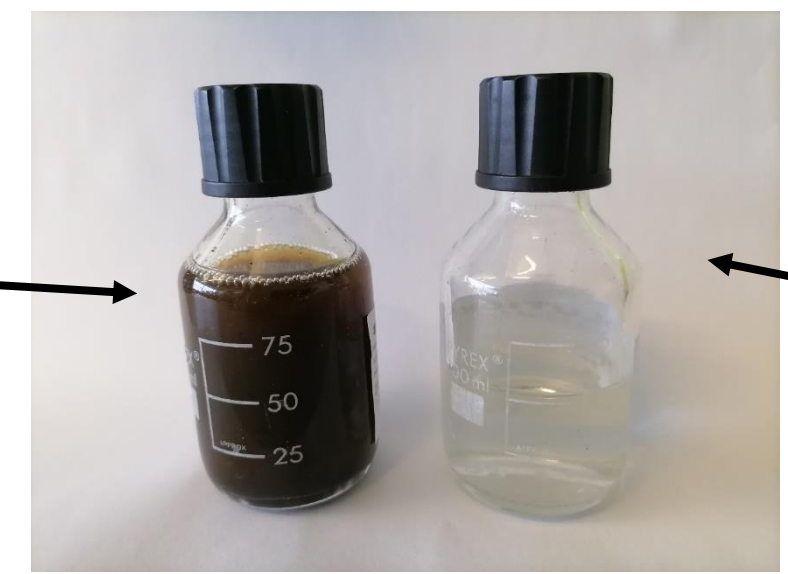


1 TWh per year of energy available if all recovered

Ammonia recovery from wastewater

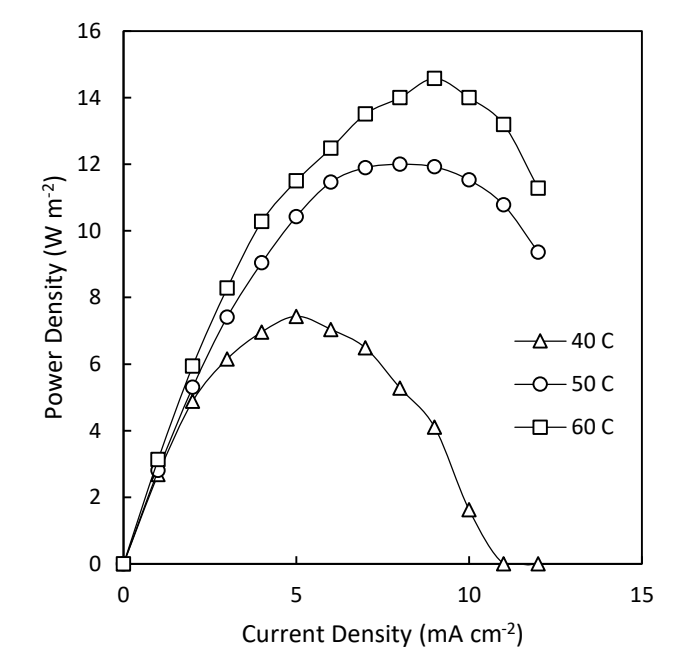
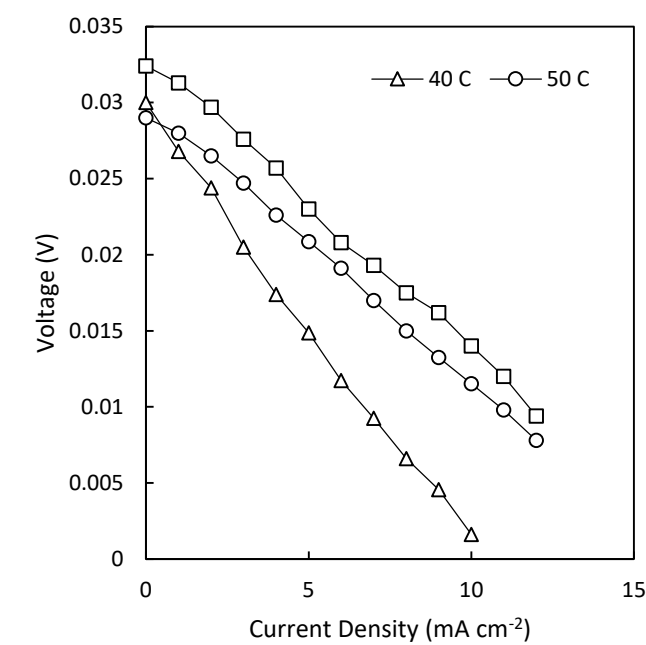
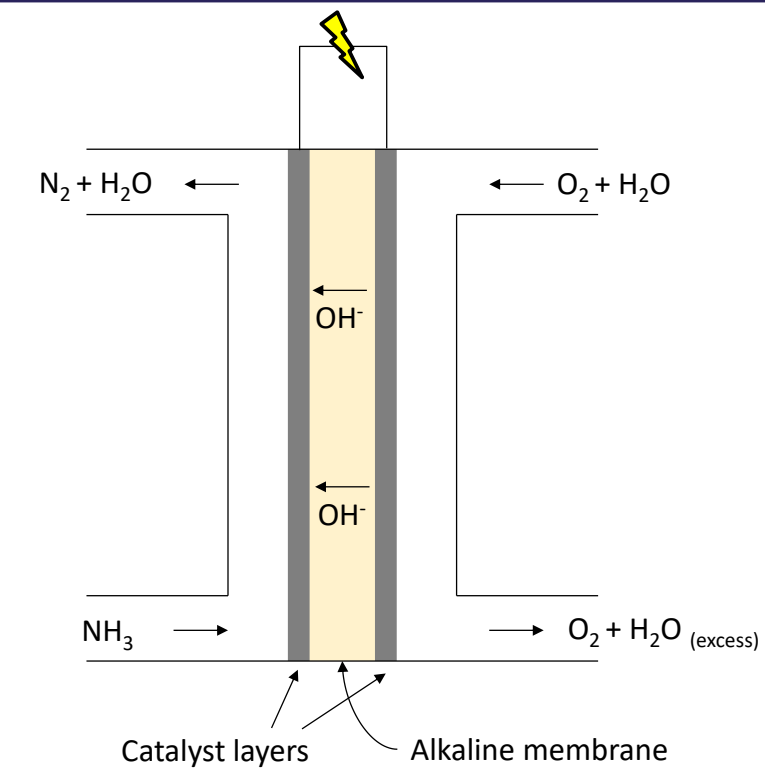
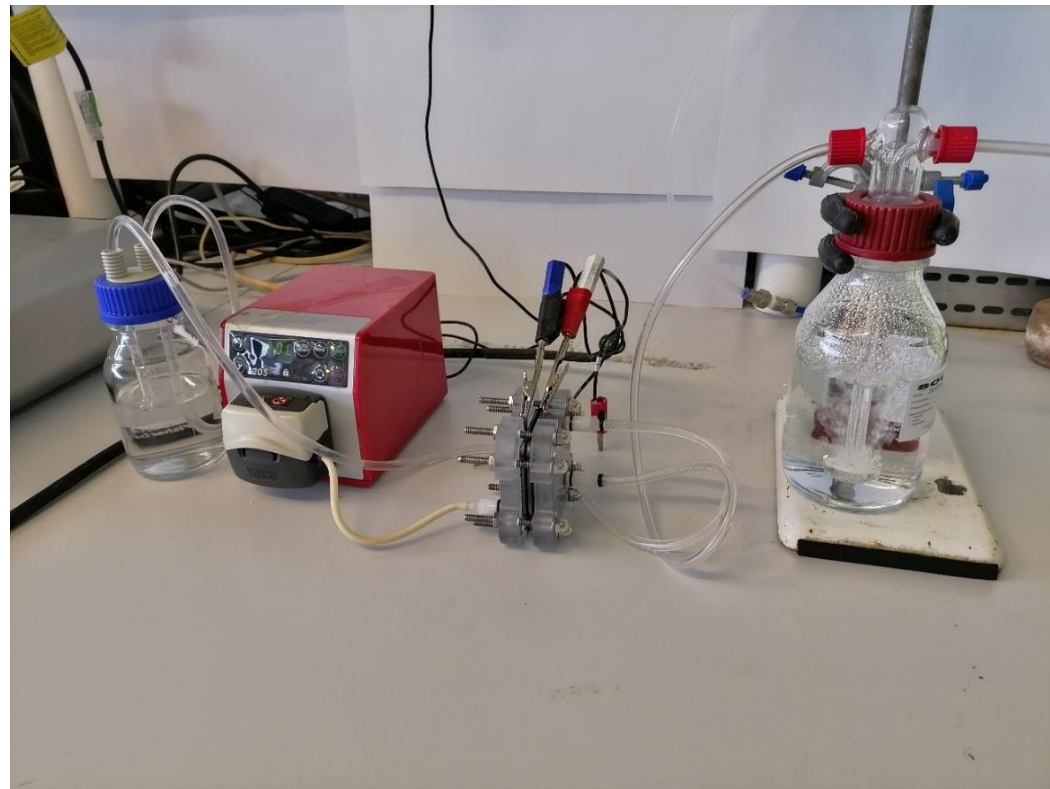


Centrate
 $\sim 0.1M NH_3$
 $\sim 6 gCOD L^{-1}$

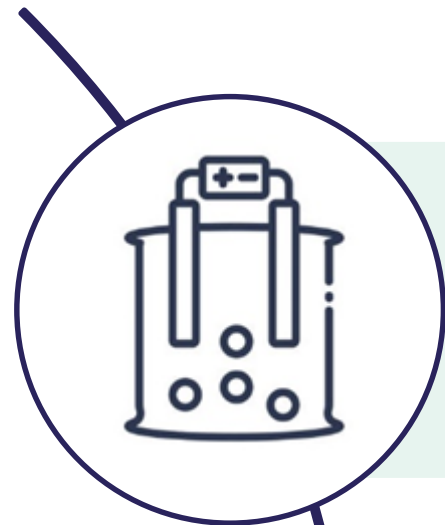


Product
 $\sim 3M NH_3$
 $0.5 - 0.05 gCOD L^{-1}$

Ammonia to energy: direct ammonia fuel cell



Next Steps



Demonstrate ammonia to hydrogen

- $2\text{NH}_3 \rightarrow 3\text{H}_2 + \text{N}_2$
- Ammonia has added value as hydrogen (RTFO), PEM fuel cell more mature technology



Scale-up

- Demonstrate integrated ammonia recovery and utilization at scale



Define Value

- What is the most valuable pathway for ammonia product?
- Further develop direct ammonia or shift to ammonia to hydrogen?