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Chevron Climate Energy Environment Webinar Series

A comparative assessment framework for sustainable production of fuels and chemicals explicitly accounting for intermittency

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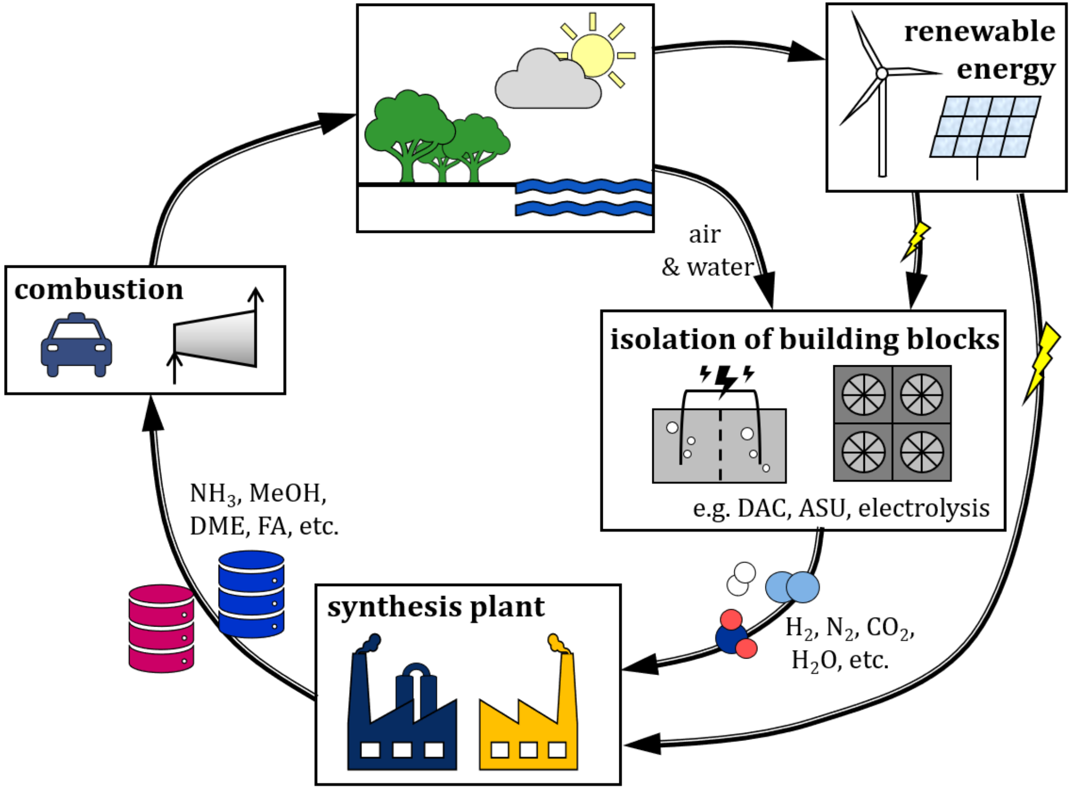
Introduction – circular economy for fuels



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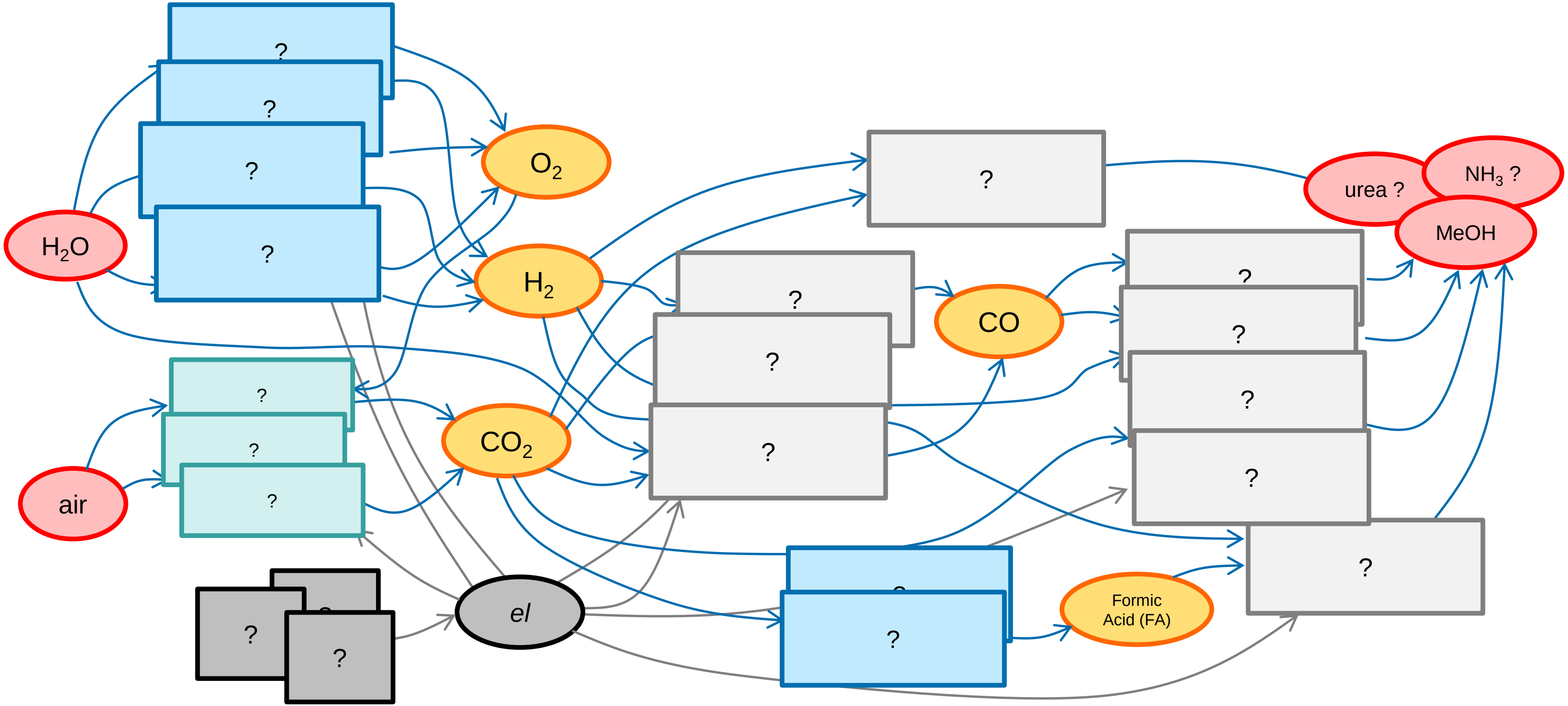
Introduction



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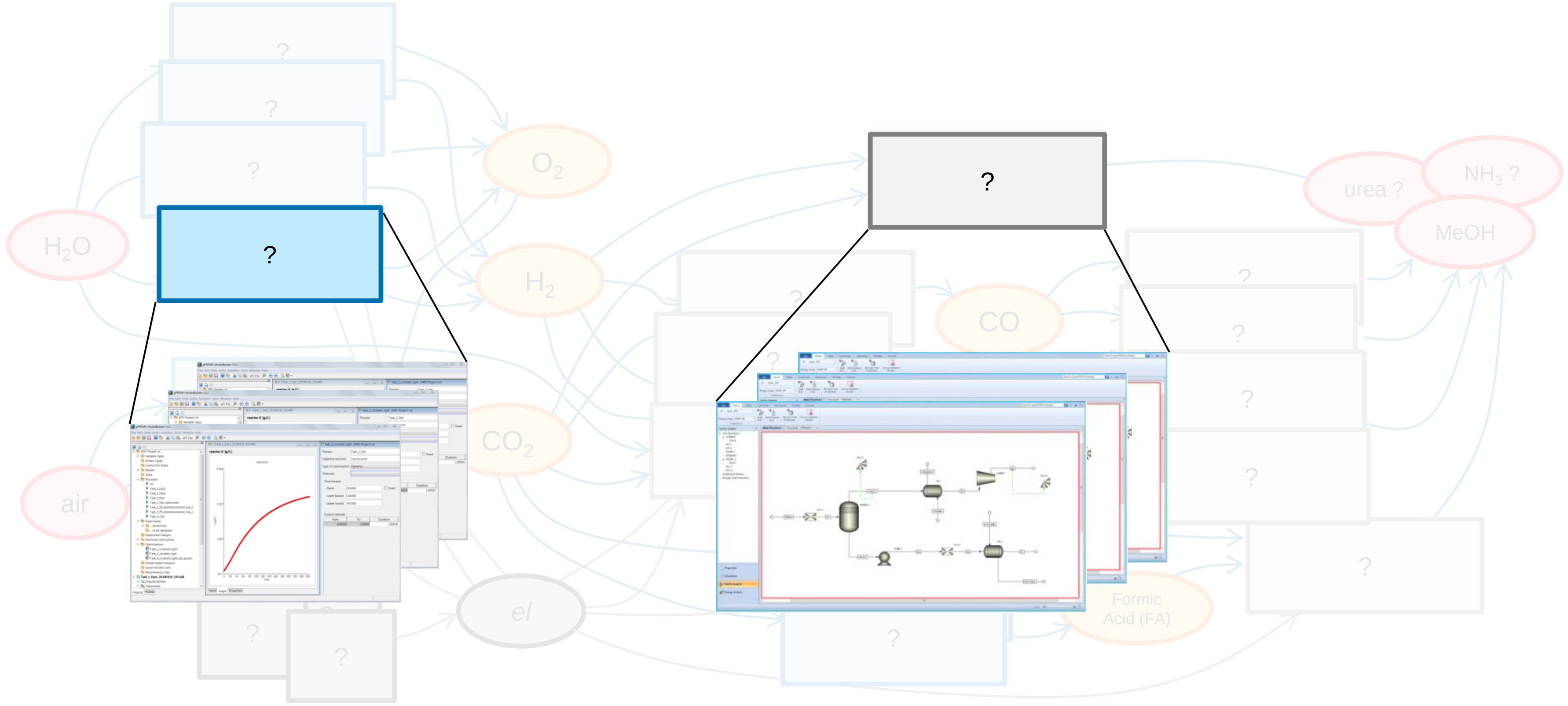
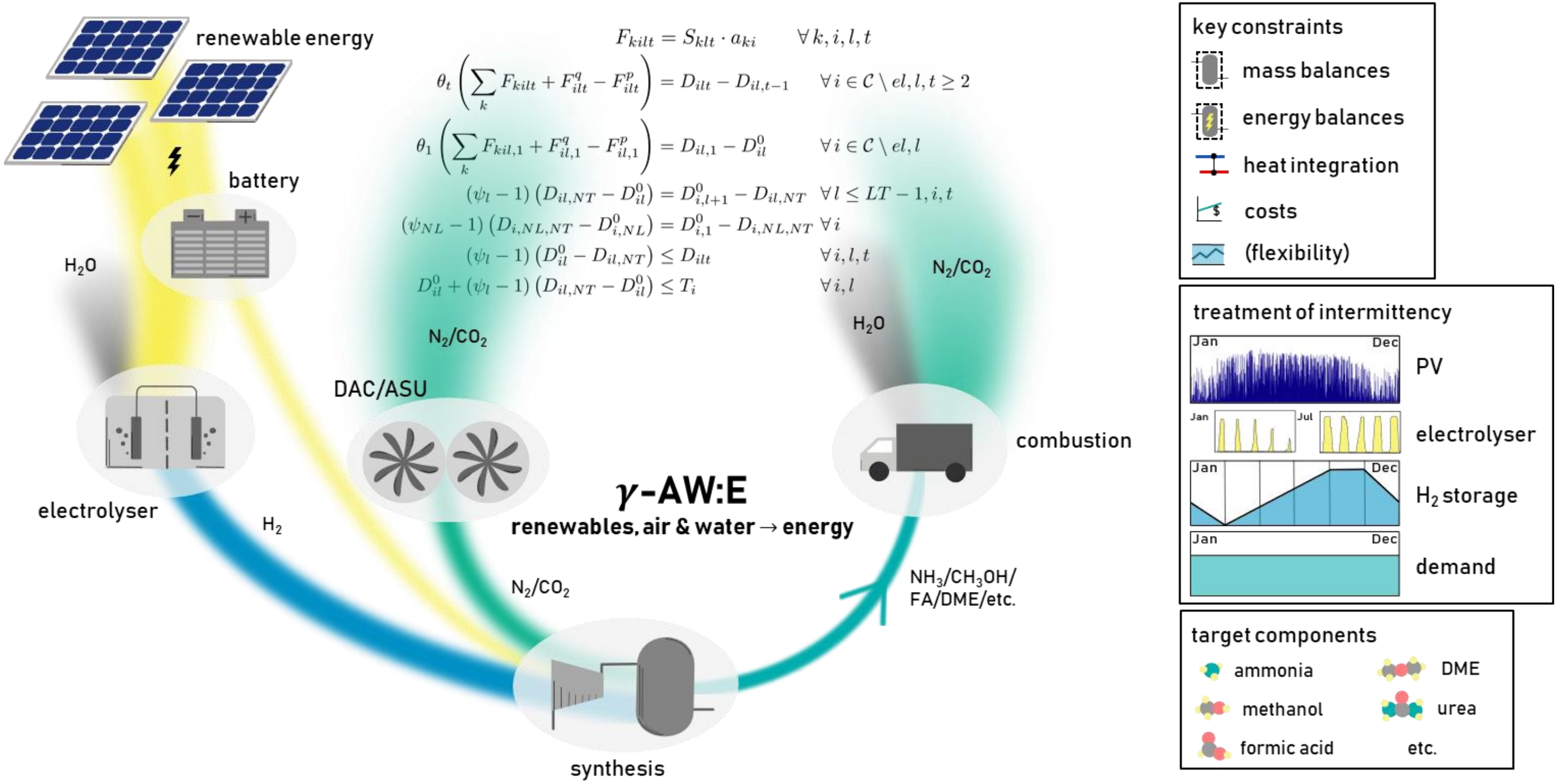
Introduction



Our model



Ganzer, Caroline, and Niall Mac Dowell. *Sustainable Energy & Fuels* 4.8 (2020): 3888-3903.

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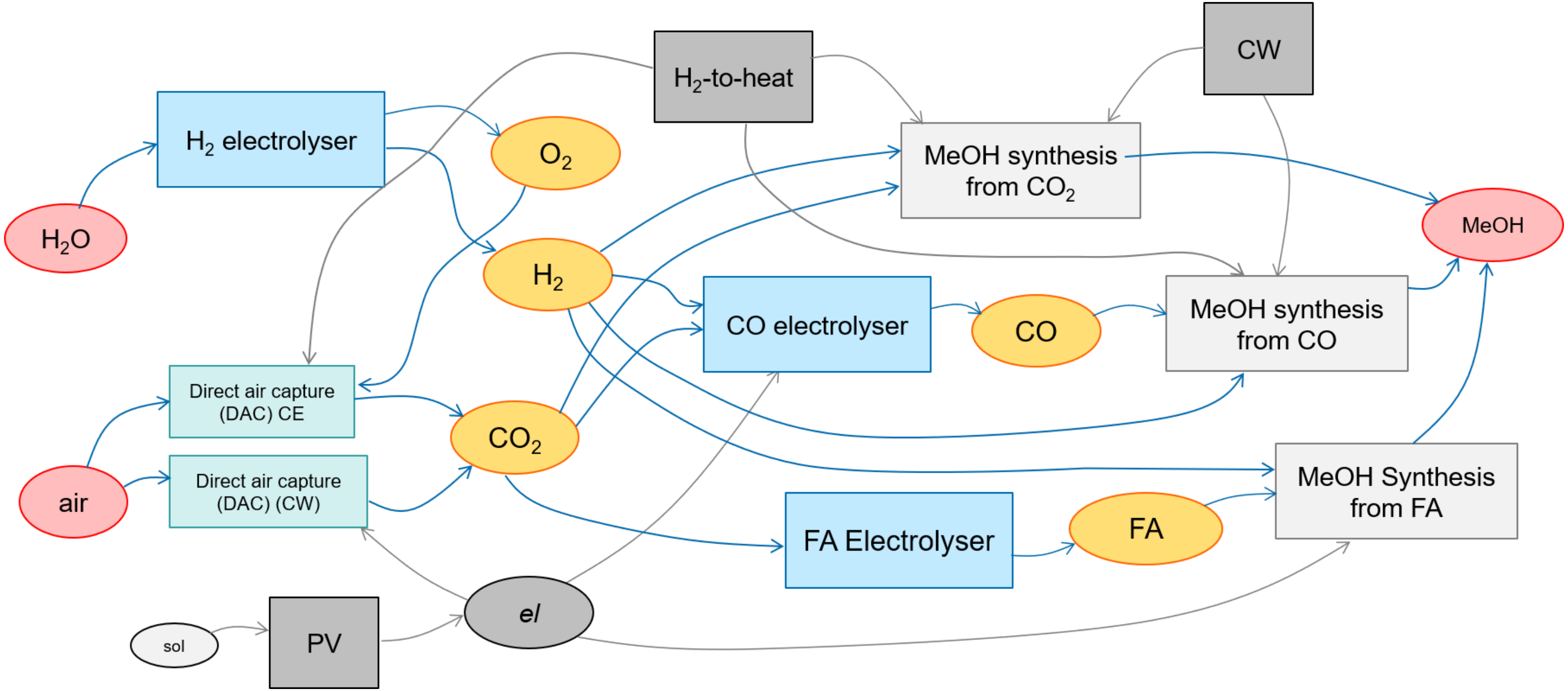
Production routes for methanol



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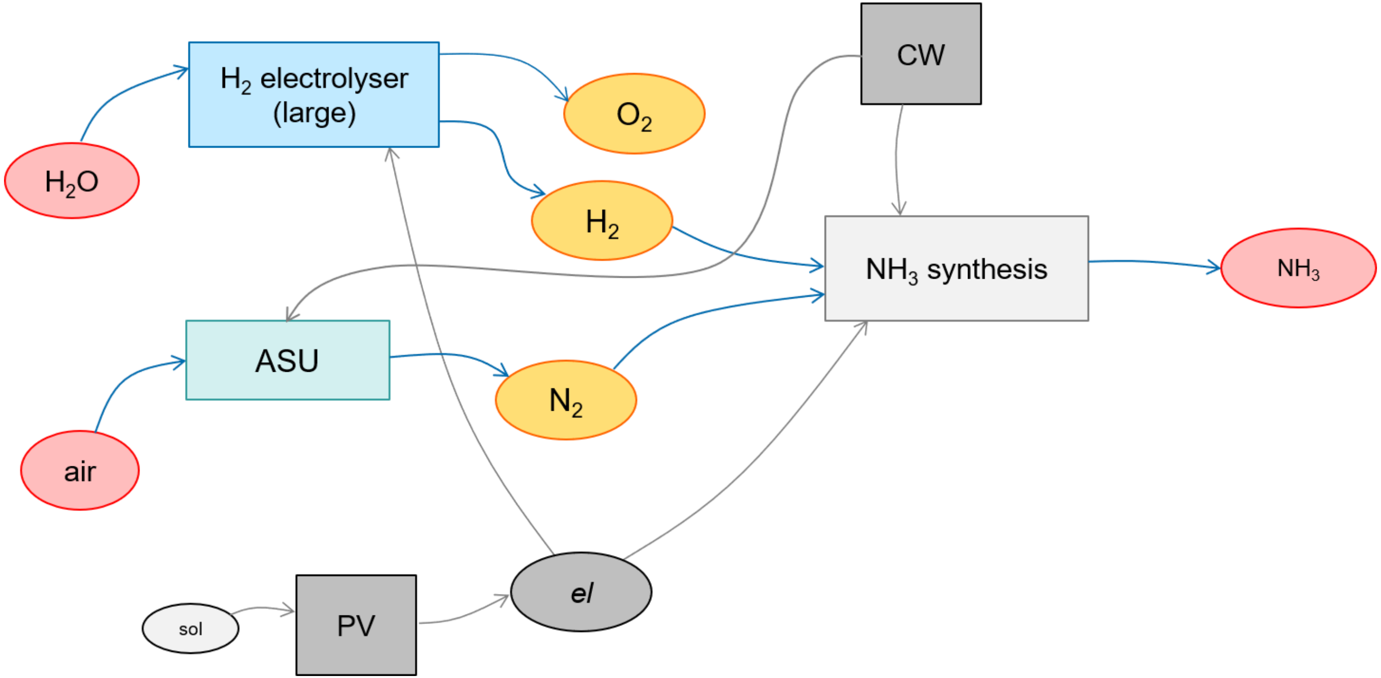
Production routes for ammonia



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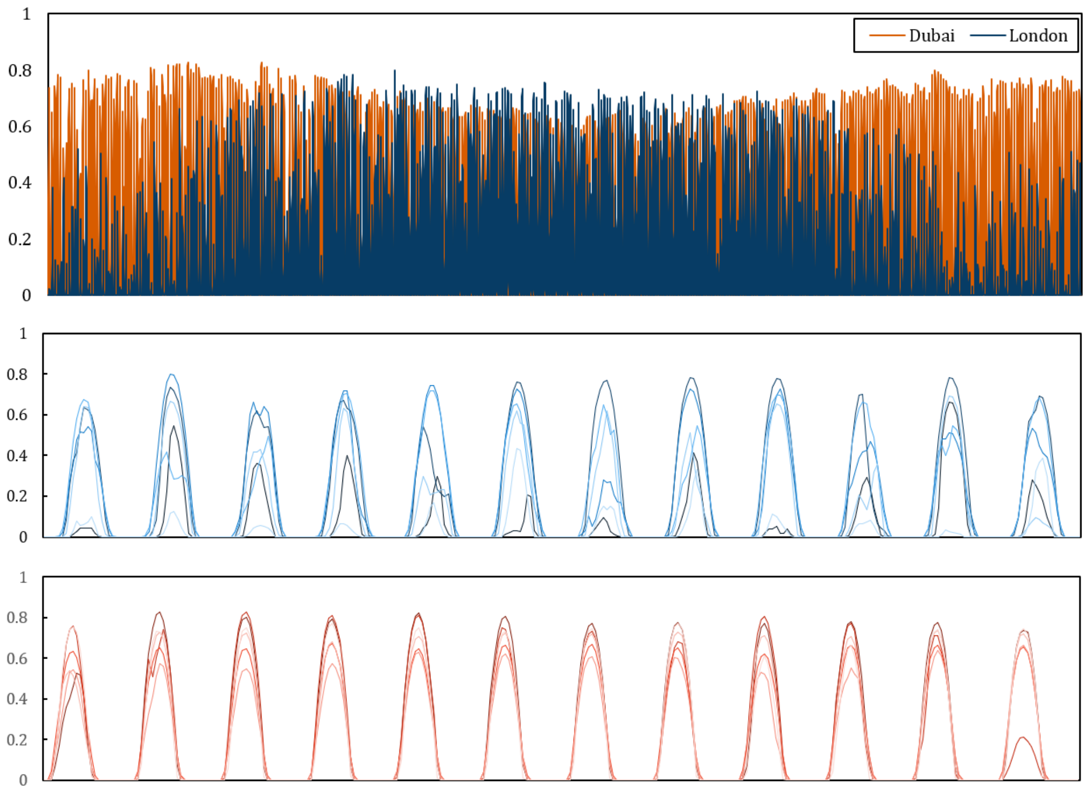
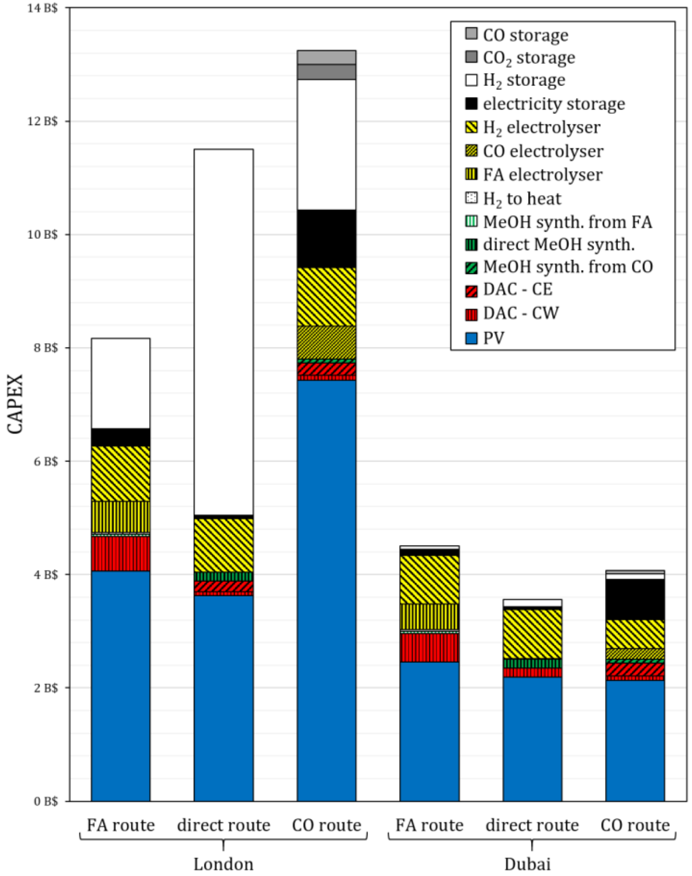
PV profiles



We examine systems in seasonal (London) and non-seasonal (Dubai) climates.

Comparison of methanol routes



PV, electrolyser and H_2 storage dominate the cost.

The optimal route for MeOH depends on the location. In London, the route via FA is optimal, reducing the cost of seasonal storage. In Dubai, the direct route is best due to lower PV & electrolyser cost.

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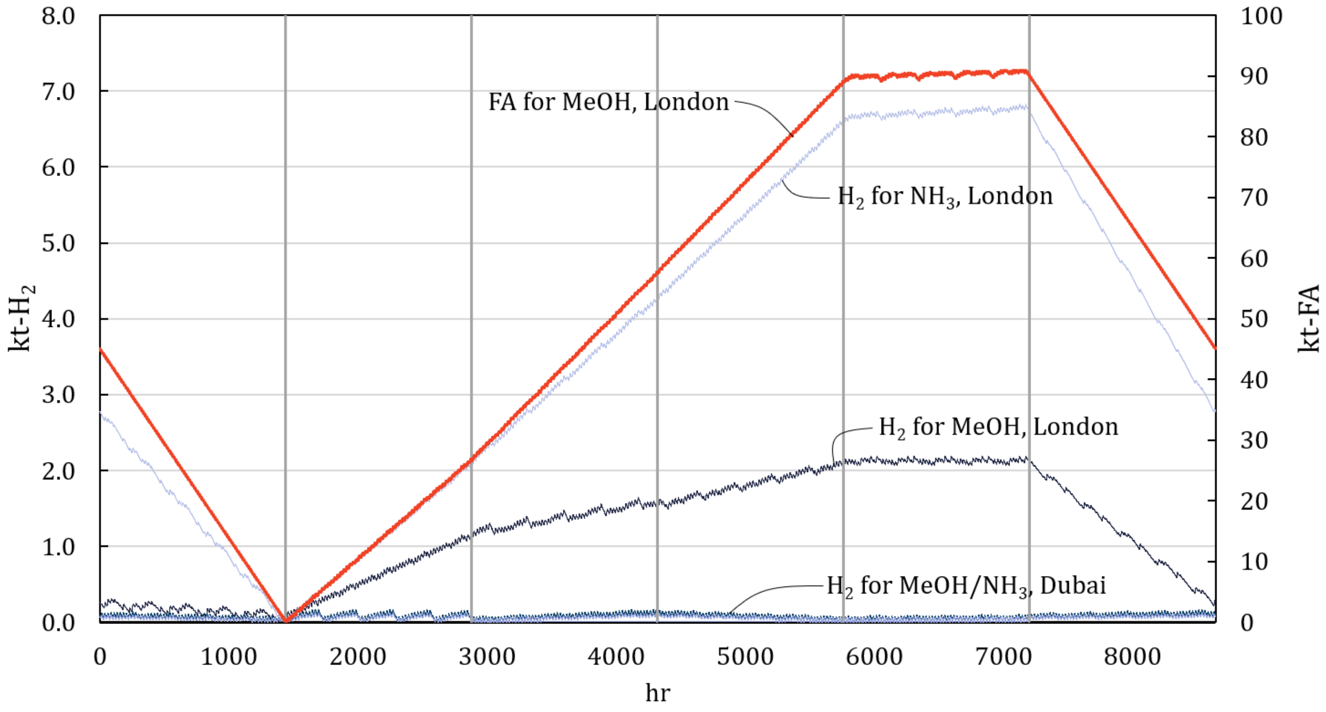
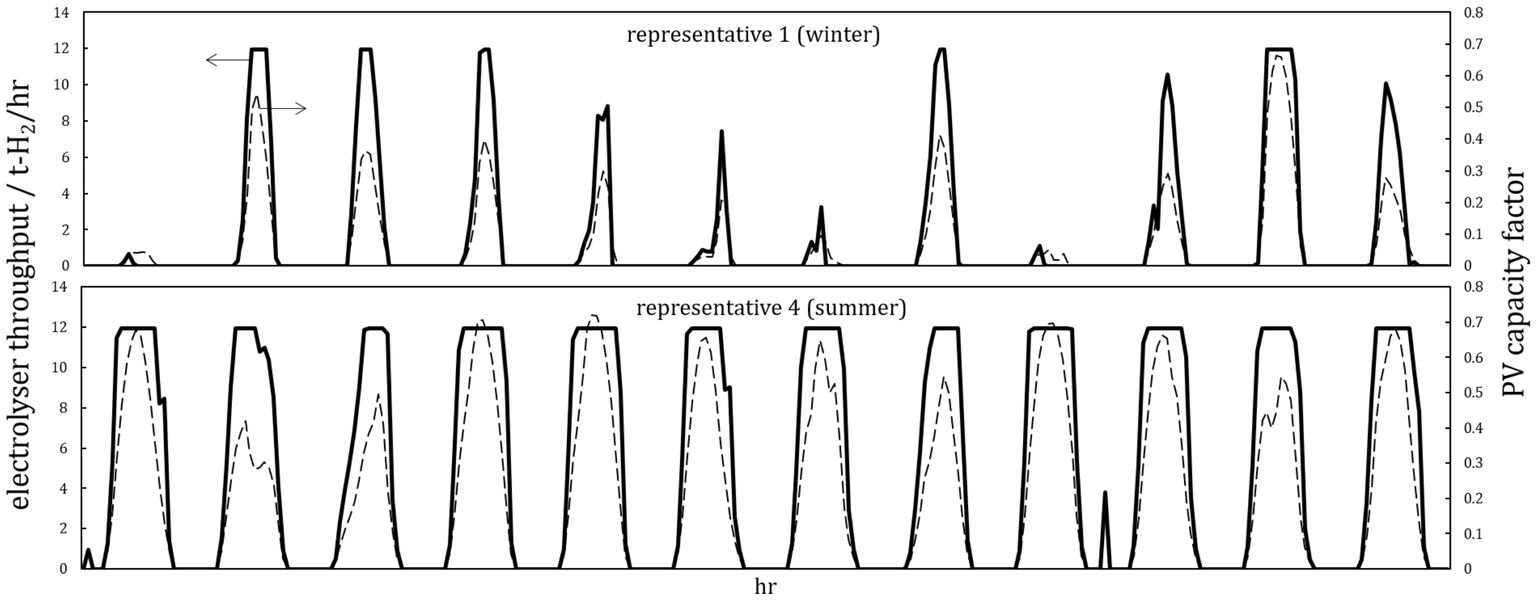
Storage levels



H_2 storage for seasonal storage and battery storage for balancing daily fluctuation are optimal.

Electrolyser throughput in summer and winter



In the optimal schedule, the electrolyser follows the radiation pattern. Additional electrolyser capacity is preferred over additional battery storage.

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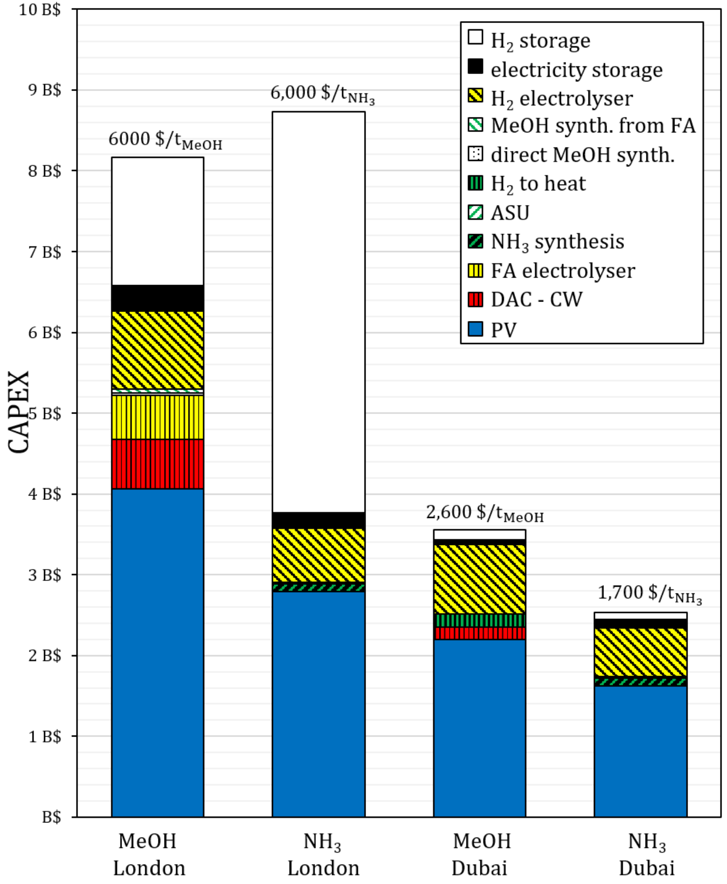
MeOH vs. NH_3



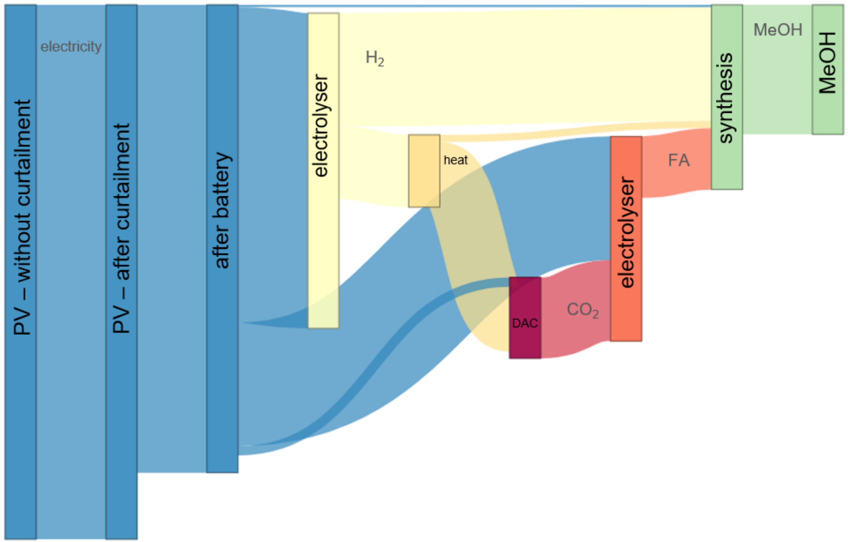
In Dubai, no seasonal storage is required, reducing the cost dramatically.

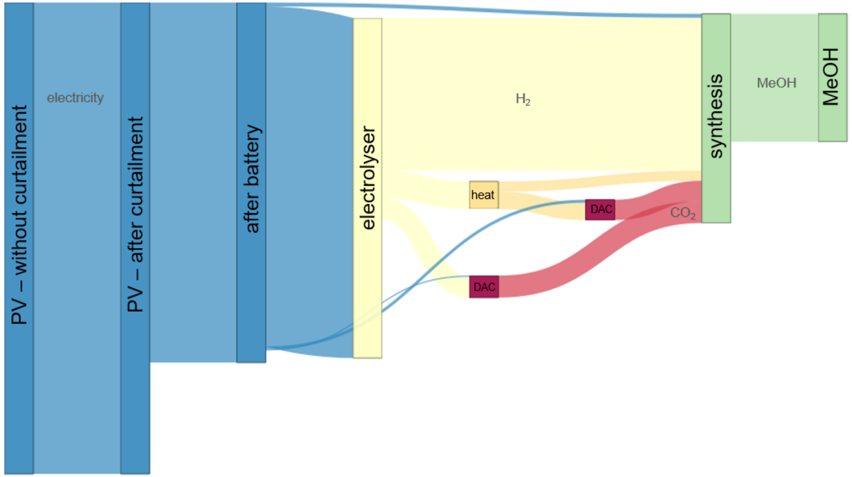
In London, NH_3 and MeOH costs are similar, whereas in Dubai NH_3 is cheaper.

Current prices are 400-500 $/t-MeOH and 500-600 $/t-$NH_3$.

Priorities for cost reduction are PV, electrolysis, H_2 storage. Impacts of cost reduction of synthesis are negligible.

Energy flows – MeOH – London





In a seasonal climate like London, any route which can reduce the cost of seasonal storage is advantageous. FA storage being cheaper than H_2 storage, a route via FA is optimal, even though higher PV and electrolyser capacities are needed.

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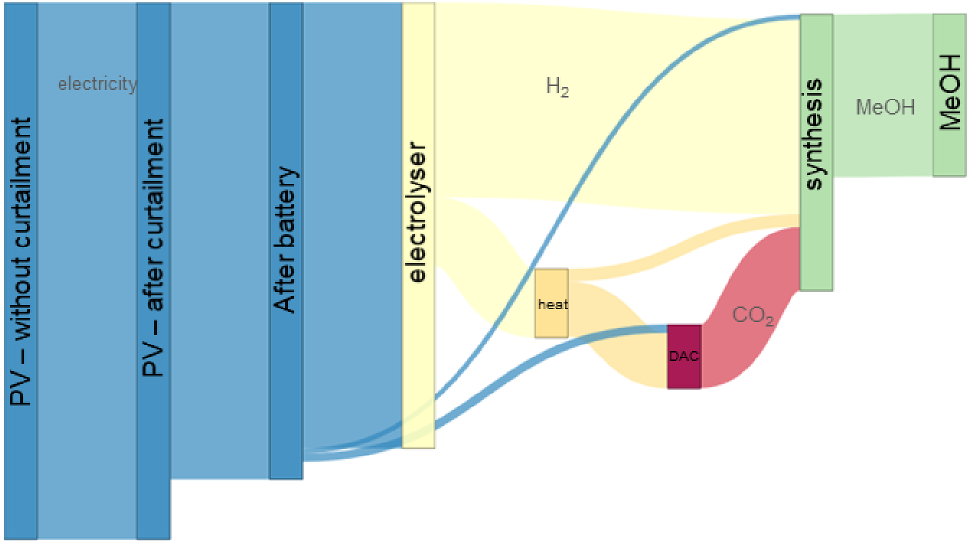
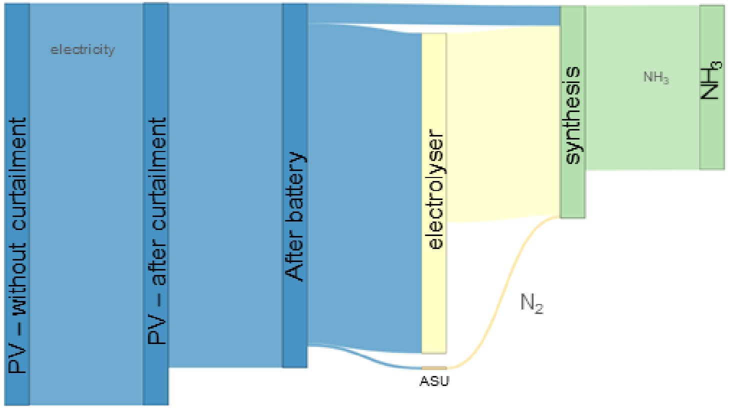
Energy flows – NH_3 vs. MeOH – Dubai





CO_2 is significantly less abundant and more chemically stable than N_2. N_2 can be obtained at negligible energetic cost. Additional PV and electrolyser capacity are needed for the separation and chemical activation of CO_2.

Nitrogen-based fuels may offer advantages over carbon-based fuels in a post-fossil sustainable future.

Comparison of EROI to other fuels

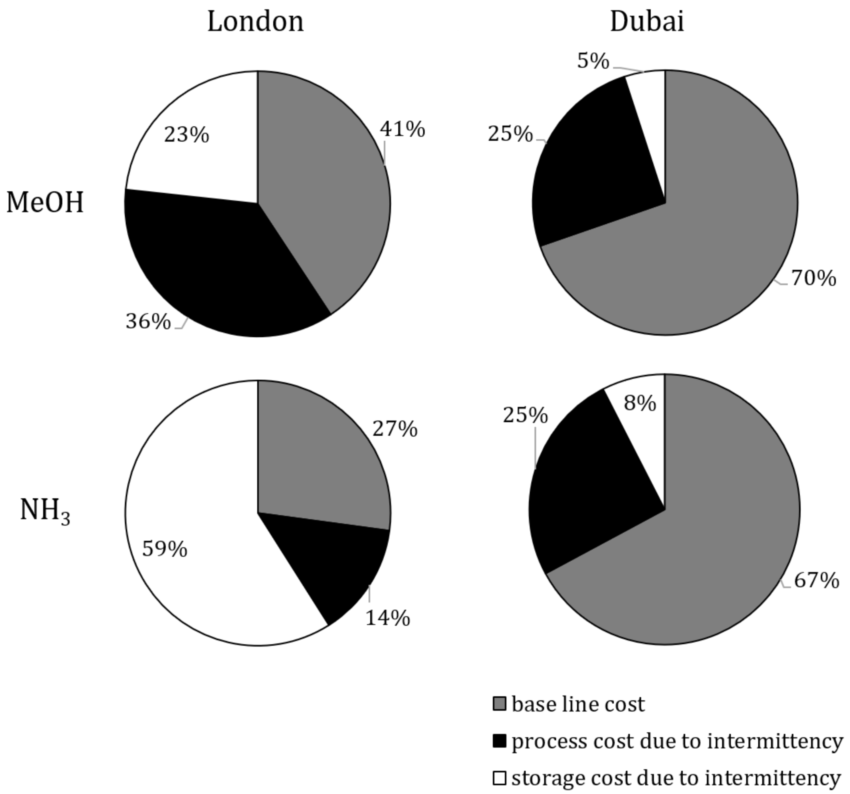
	London	Dubai
Methanol	2.4	4.5
Ammonia	3.5	6.1
Corn-based bioethanol	1.1 – 1.65	
Cellulose-based bioethanol	4.4 – 6.6	
Sugarcane-based bioethanol	3 – 10	
Algae-based biofuels	0.14 – 3.35	
Biodiesel	2	
Oil & gas	10 – 70	

While not competing with traditional fuels, methanol and ammonia from air, water and renewable energy may challenge bio-based sustainable fuels.

Synthetic fuels as opposed to biofuels have fewer drawbacks regarding competition for resources and biomass carbon footprint. Biofuels on the other hand may provide negative emissions.

[2][3][4]

Cost of intermittency



Added cost due to daily and seasonal fluctuation in PV capacity factor can constitute up to two thirds of total cost.

Running chemical plants in summer (solar) mode and winter (bio) mode could be considered.

Novel fuel production technologies which are entirely flexible may be preferable in locations with high seasonal variation – even if they require higher CAPEX.

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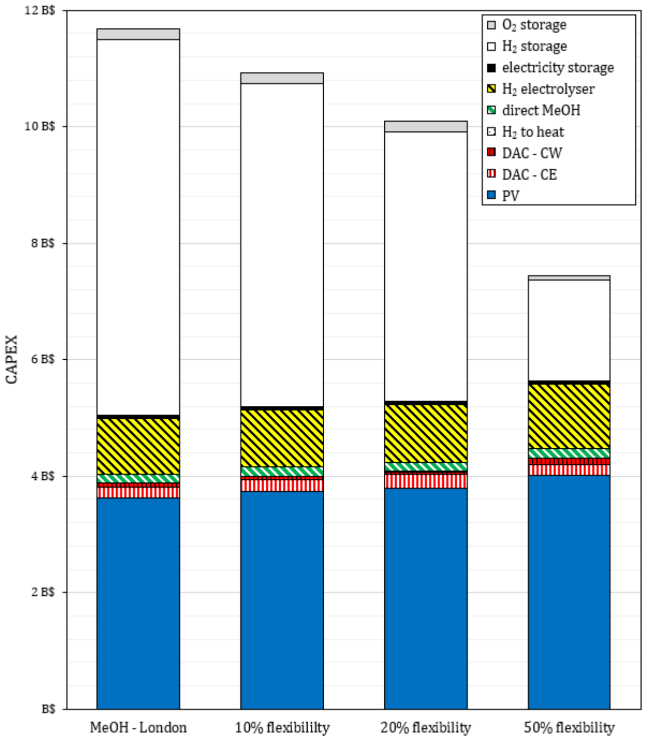
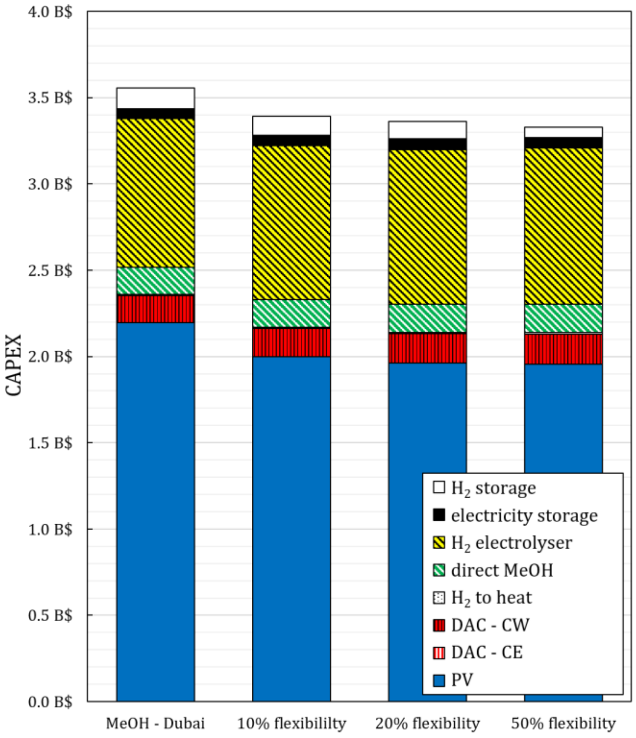
Impact of process flexibility





Increased process flexibility can reduce cost substantially.

Intermittency needs to be taken into account when designing process systems depending on renewable energy input.

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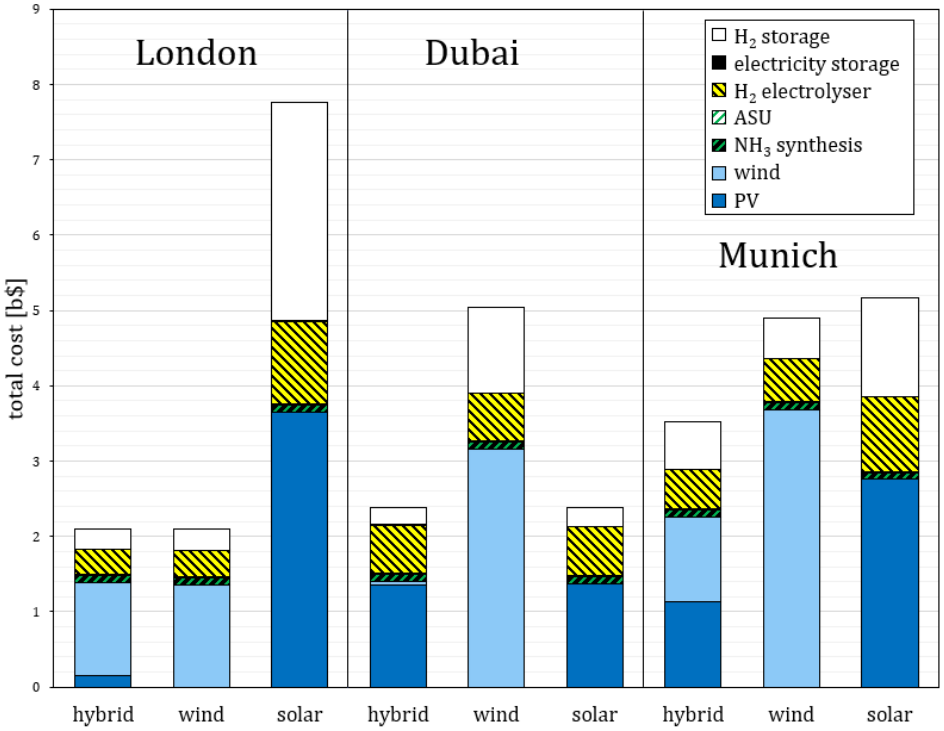
Wind vs. solar vs. hybrid systems in varying locations

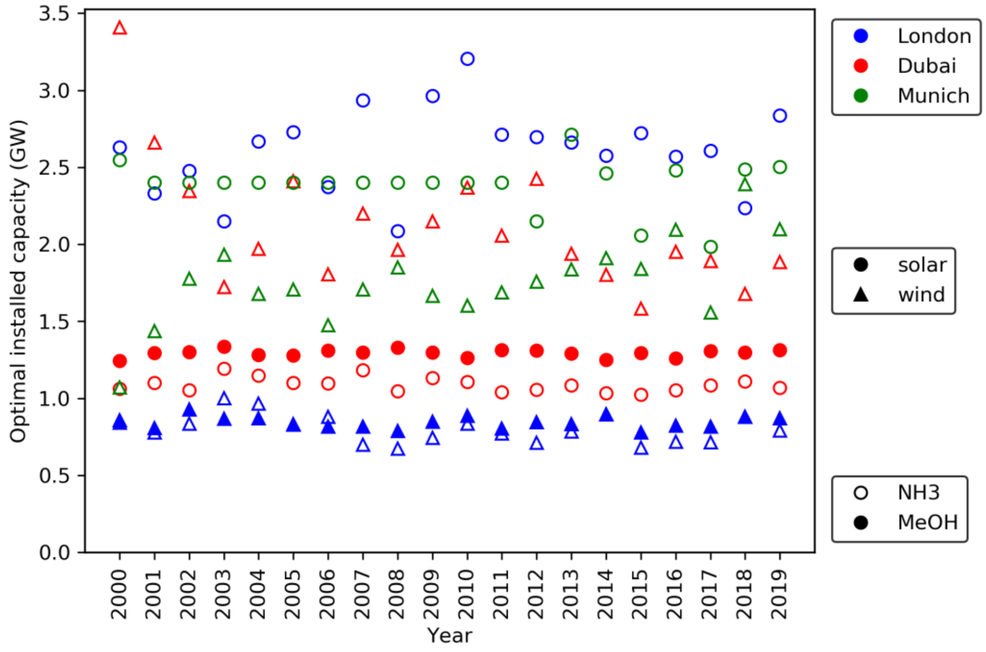


In London, wind availability is higher – a *wind-only* system is optimal.

In Dubai, solar availability is higher – a *solar-only* system is optimal.

Munich has similar wind and solar availability – a *hybrid* system reduces cost.

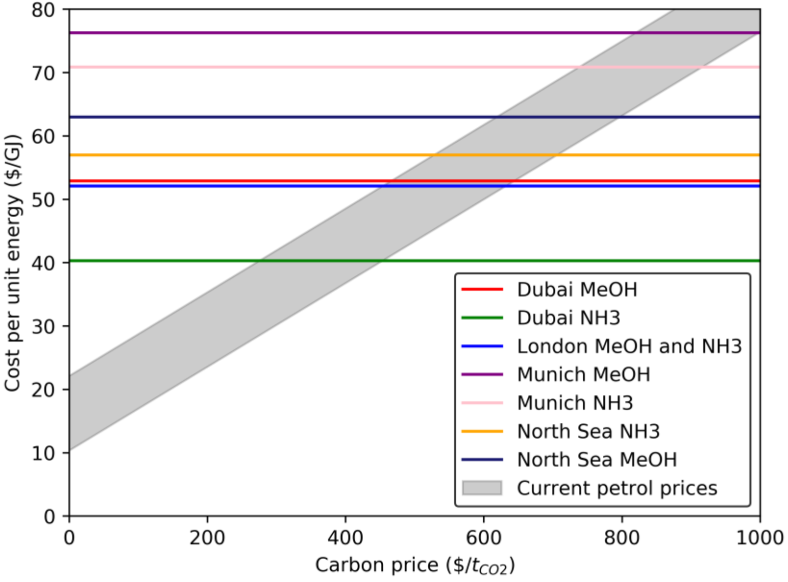
Interannual variability

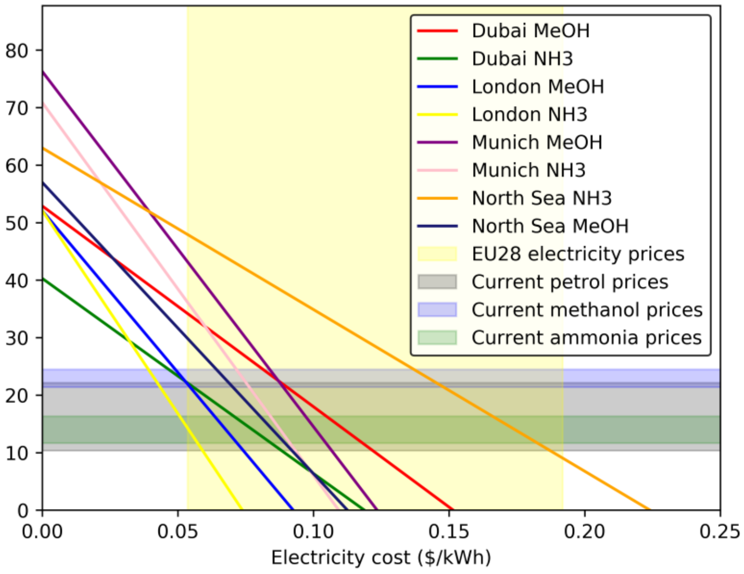


Interannual variability is significant. It depends on the power sources and the location. In these runs, capacity required in the worst year is up to 60% higher than average optimal capacity.

If steady state processes are to use only renewable, intermittent energy, the power plant may need to be oversized to account for the worst year, ensuring the production target is met throughout the lifetime.

Improving competitiveness of renewable fuels





A carbon price, the selling of excess electricity, and increased process flexibility can improve the competitiveness of renewable fuels and chemicals compared to fossil-based products.

Conclusions

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- Solar NH_3/MeOH cannot currently compete with traditional fuels in terms of cost.
- A shift from C-based to N-based fuels should be carefully considered from a circular economy perspective.
- Solar fuel production systems are strongly dependent on the location.
- The cost of intermittency is especially high in London due to the seasonal radiation pattern.
- Flexibility can lead to cost reductions in London but not in Dubai, so it can remedy the impact of seasonal but not daily intermittency.
- Priorities in cost reduction are PV, electrolysis, H_2 storage.
- Integrated assessment of renewable fuel production is required to assess the value of novel technologies and the actual production cost.

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