Electricity storage with liquid fuels in a zone powered by 100% variable renewables

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Overview

Introduction

- European Commission goals to reduce greenhouse gas emissions by at least 80 percent below 1990 levels by 2050.
- Renewable sources but time-varying nature of these resources
- The benefits of storage are numerous:
  - Arbitrage possibilities on the energy market (balancing capabilities)
  - Contingency reserves
  - Black start capabilities

Introduction

In the present work, we study a storage technology that uses electricity to produce methanol : The main advantage of liquid fuels is their high energy density per unit mass (22.4 MJ/kg) and per unit volume (17.8 MJ/L).

- Methanol storage is cheap and easy
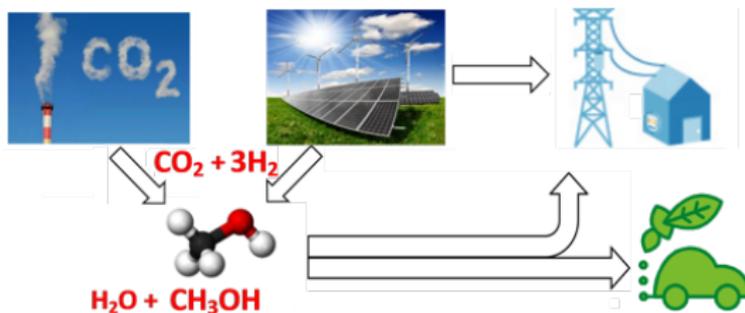- Methanol may also be considered as a CO2-neutral energy carrier.

Figure : Scheme of the power-to-fuel process using methanol

Introduction

Electricity zone powered by 100% variable renewables.

- In this zone, we assume that the only primarily source for electricity generation is wind power.
- No market competitiveness is considered in the model

	Wind power unit	**Storage unit**
Net unit capacity	5 MW	0.25 MW
Capex costs	1100 €/kW	856 €/kW
Fixed O&M costs	1.7% of Capex per year	25 €/kW/year
Opex costs	0 /kWh	$6\ 10^{-3}$ €/kWh
Lifetime	25 years	20 years
Interest rate	7%	7%

Representative data from a real electricity zone:

- For the demand, we use historical data provided by the Belgian TSO for a three-year period from January 19, 2012 to January 18, 2015.

- For the supply, we use instantaneous time-varying wind generation and wind capacity data to infer the time-varying wind capacity factor for the same zone.

Modeling

The optimization model consists in minimizing the average cost of electricity while considering two constraints.

- Demand is served at any time.
- Same amount of methanol stored at the end of the three-year period as at the beginning.

Results

- Installed wind and storage capacities of 44.6 GW and 13.5 GW respectively.
- The share of electricity that is directly served by wind equals 74.6%. The curtailment rate of wind power is 13.3%.

It leads to an electricity cost of 83.4 €/MWh that is less than twice the current average electricity price in the Belgian market (45.1 €/MWh over the same period).
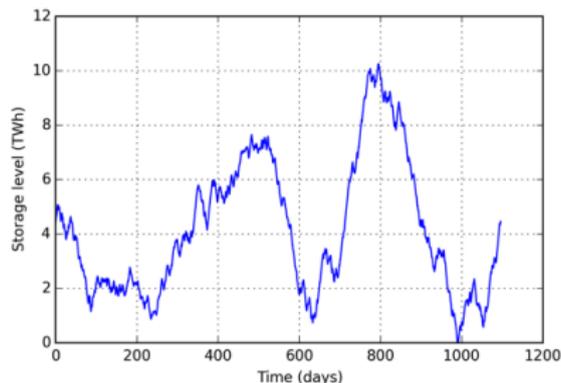
Figure : Evolution of the storage level with time (base case)
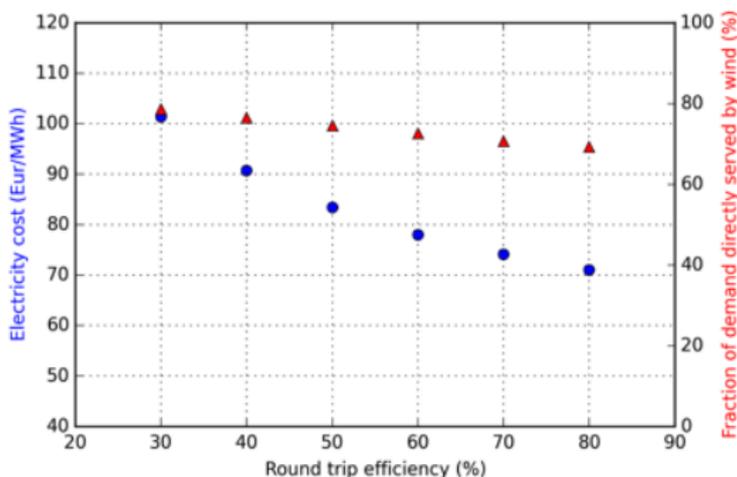
Sensitivity analysis

Figure : Electricity cost as function of storage round-trip efficiency
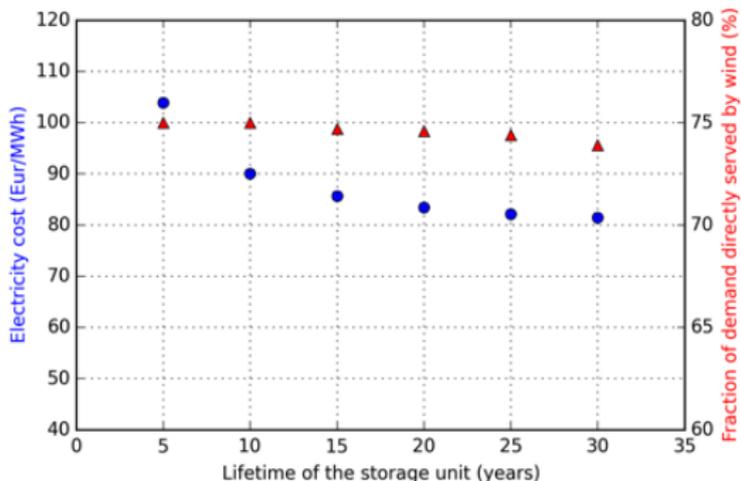
Figure : Electricity cost as function of the storage lifetime

Further work and forecast

- Higher capacity factor for on-shore wind may be obtained by 2050 up to an average value of 45%. Much higher than the average capacity factor of 29% obtained from historical data in the present model.
- Other renewables like solar and hydro power may be included into the model. This will lead to a configuration closer to the reality with lower supply variability (and thus a smaller need for storage) thanks to the different generation time profiles of these variable renewables.
- Another advantage is the flexibility of use offered by liquid fuels, as they can be used either to generate electricity or as fuel substitute for mobile applications

Thank you for your attention

References

📄 Léonard, Grégoire and François-Lavet, Vincent and Ernst, Damien and Meinrenken J, Christoph and Lackner S, Klaus

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