Lecture 12: Multi-carrier energy systems II: aviation, shipping, industry

DTU Course 46770: Integrated Energy Grids

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Problem 12.1. In this problem, we want to build a stylized mode of hydrogen production in an energy island. Assume an offshore generator and an electrolyzer with the cost in Table 1. For the offshore generator, assume the capacity factors for Denmark in `https://zenodo.org/record/3253876#.XSiVOEdS8l0`.

An annual hydrogen demand of 200 GWh must be delivered, and for the sake of simplicity, assume that the island includes a hydrogen storage with no cost. The electrolyzer efficiency is assumed to be 62%.

Technology	Annualized capital costs (EUR/MW/a)	Marginal generation costs (EUR/MWh)
Offshore Wind	174,556	0
Electrolyzer	188,715	0

Table 1: Costs assumptions.

a) What is the optimum capacity of offshore wind and electrolyzer that needs to be installed?

b) What is the optimal storage capacity of hydrogen, in absolute terms and relative to the annual demand?

c) Plot the duration curve for offshore wind generation and electrolyzer operation and discuss the results. Compare the capacity factor corresponding to wind power availability and the utilization factor for the electrolyzer.

d) At what cost can the H_2 be produced and how does it compare to current H_2 price?

Problem 12.2. In this problem, we want to build a stylized mode of methanol production in an energy island. Assume an offshore generator, an electrolyzer, a Direct Air Capture (DAC) unit ,and a methanolisation unit with the cost in Table 2. For the offshore generator, assume the capacity factors for Denmark in `https://zenodo.org/record/3253876#.XSiVOEdS8l0`.

An annual methanol demand of 200 GWh must be delivered and, for the sake of simplicity, assume that the island includes a hydrogen storage, a CO_2, and a methanol storage with no cost. The electrolyzer efficiency is assumed to be 62%. The methanolisation plant requires hydrogen, CO_2 and electricity as inputs. It produces 0.8787 MWh of methanol per MWh of hydrogen, 4.0321 MWh of methanol per tonne of CO_2, and 3.6907 MWh of methanol per MWh of electricity.

The DAC unit requires 0.55 MWh of electricity and 1.4 MWh of heat to capture 1 tonne of CO_2. Heat is assumed to be provided by a heat pump with a constant coefficient of performance (COP) of 3.

a) What is the optimum capacity of offshore wind, electrolyzer, DAC, and methanolisation that needs to be installed?

b) What is the optimal storage capacity of hydrogen, CO_2, and methanol, in absolute terms and relative to the annual demand?

Technology	Annualized capital costs (EUR/MW/a)	Marginal generation costs (EUR/MWh)
Offshore Wind	174,556	0
Electrolyzer	188,715	0
Methanolisation	87,538	0
Direct Air Capture (DAC)	863,357	0
Heat pump	79,870	0

Table 2: Costs assumptions.

c) Plot the duration curve for the offshore wind generation, electrolyzer, DAC and methanolisation operation and discuss the results.

d) At what cost can the methanol be produced and how does it compare to current methanol price?