1. H_2 filling station

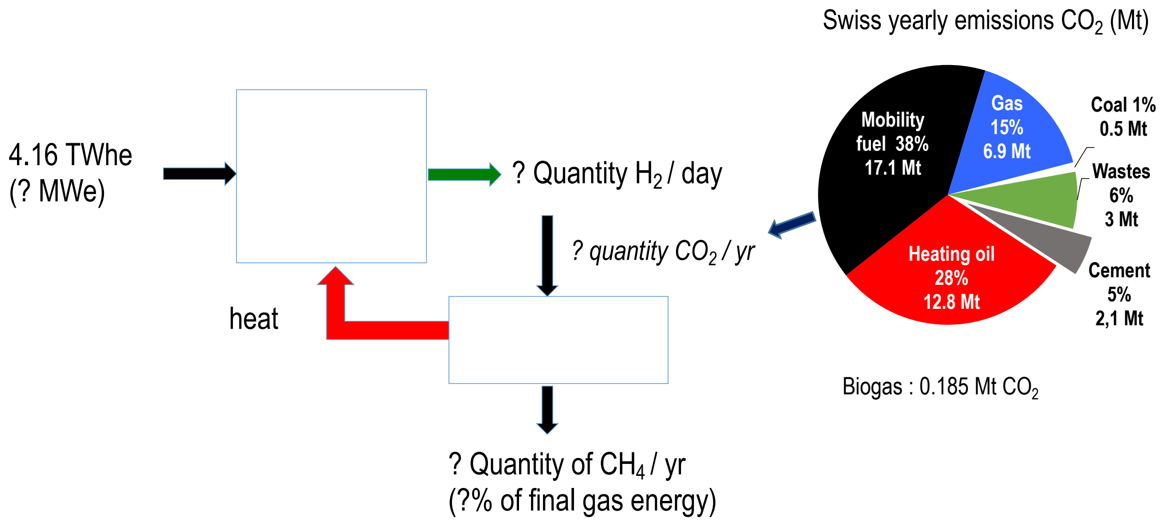
How big an electrolyser is needed to produce the daily amount of H_2 for a filling station (HRS: hydrogen refuelling station)), under the following assumptions?:

- 1000 cars/day, equivalent of 50 L gasoline/car (LHV_gasoline: 33 MJ/L)
- car average consumption : 7 L gasoline/100km
- a FCEV (fuel cell electric vehicle) consumes 1 kg H_2/100km (HHV_H_2 : 142 MJ/kg)
- water electrolyser efficiency (electricity → H_2): 78% HHV
- compression energy needed to 400 bar (Roughly 8% of HHV)
- the electrolyser operates 50% of the time
- Extrapolate the electrolysis power needed for 150 HRS, which is ~the quantity of existing natural gas filling stations in Switzerland, enough to cover most of the territory. Comment.

Solution:

- filling station, 1000 cars/day, 50 L gasoline/car
- => 50'000 L gasoline/day yields 50000/7 = 7143 kg H_2 /day in terms of equivalent consumption per 100 km = 1014 GJ/day in H_2 energy filled in 1000 cars
- electrolyser efficiency 78% → 1300 GJ/day electricity input needed
- 50% load = 12h : 1300 GJ/(12h x 3600s) = 30 MWe electrolyser
- compression to 400 bar : roughly 8% of HHV needed=> requires extra 104 GJ/day of electricity = 104 GJ/(12h x 3600h) = 2.4 Mwe
- hence a total power of at least 32.4 MWe needed at the filling station
- for 150 HRS this amounts to 4.86 GWe, equivalent to 5 nuclear power stations

2. Power-to-gas



Switzerland stores yearly about 4 TWhe of electricity via hydro-pumping (200 GWhe per month). Assume instead that this amount of electricity were used to generate H_2 via electrolysis, which would then be combined with CO_2 in a methanation reaction to produce synthetic methane CH_4 for injection into the natural gas grid.

- Assume ~continuous operation: what is the installed electrolysis power? (MWe)
- Using 100% efficiency for steam to H_2 electrolyis, how much H_2 is generated per day? (m^3/day)
- How much CO_2 is needed for methanation? ($4\ H_2 + CO_2 \Leftrightarrow CH_4 + 2\ H_2O$)
- How does this compare with Switzerland's CO_2 emissions?
- How much CH_4 would be generated per year?
- How does this compare to the yearly Swiss natural gas consumption of 35 TWh (126 PJ)?

Solution:

4.16 TWhe / (8760 h/yr) = 475 MWe electricity input
100% efficiency => 475 MW equivalence in H_2
With 142 MJ/kg, this corresponds to 475 / 142 = 3.34 kg H_2/s

- ⇨ *3600 s : 12042 kg/h
- ⇨ *24 h : 289'014 kg/day
- ⇨ (H_2 density 0.09 kg/m^3) : 3.21 million m^3 / day

For methanation, ¼ in volume of CO_2 is required, hence 802'816 m^3 CO_2/day or (CO_2 density 2 kg/m^3) 1.6 kt CO_2/day, which times 365 days gives 0.586 Mt CO_2/yr, about 1.4% of current total Swiss CO_2 emissions.
This would then generate in theory the same volume of 802'816 m^3 CH_4/day or 293 million m^3 CH_4 per year.
As the heating value of CH_4 is considered as 10.5 kWh/m^3, this equals 3 TWh / yr, or 9% of the total Swiss yearly fossil NG consumption.