1. H_2 filling station

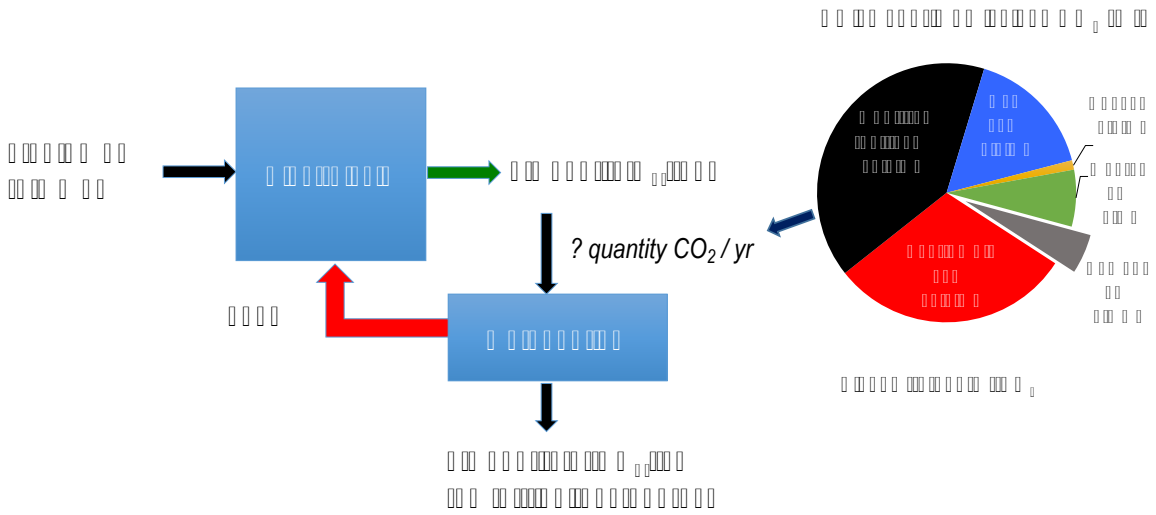
How big an electrolyser is needed to produce the daily amount of H_2 for a filling station (HRS: hydrogen refuelling station)), under the following assumptions?:

- 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_2/100 km (LHV_H_2 : 120 MJ/kg)
- water electrolyser efficiency (electricity → H_2): 68% LHV
- compression energy needed to 400 bar (estimate as % 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 = 857 GJ/day in H_2 energy filled in 1000 cars
- electrolyser efficiency 68% LHV → 1260 GJ/day electricity input needed
- 50% load = 12h : 1260 GJ/(12h x 3600s) = 29 MWe electrolyser
- compression to 400 bar : roughly 10% of LHV needed=> requires extra 126 GJ/day of electricity = 120 GJ/(12h x 3600h) = 2.9 MWe
- hence a total power of at least 32 MWe needed at the filling station
- for 150 HRS this amounts to 4.8 GWe, equivalent to 5 nuclear power stations

2. Power-to-gas



Switzerland stores yearly about 4 TWhe of electricity via hydro-pumping (350 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 ⇔ CH_4 + 2 H_2O)
- How does this compare with Switzerland's CO_2 emissions? (43 Mt/yr)
- How much CH_4 would be generated per year?
- How does this compare to the yearly Swiss natural gas consumption of 36 TWh (130 PJ)?

Solution:

4.16 TWhe / (8760 h/yr) = 475 MWe electricity input
100% efficiency => 475 MW equivalence in H_2
With 120 MJ/kg, this corresponds to 475 / 120 = 3.96 kg H_2/s

- ⇨ *3600 s : 14250 kg/h
- ⇨ *24 h : 342 ton/day
- ⇨ (H_2 density 0.09 kg/m^3) : 3.8 million m^3 / day

For methanation, ¼ in volume of CO_2 is required, hence 950'000 m^3 CO_2/day or (CO_2 density 2 kg/m^3) 1.9 kt CO_2/day, which times 365 days gives 0.693 Mt CO_2/yr, about 1.6% of total Swiss CO_2 emissions.
This would generate in theory the same volume of 950'000 m^3 CH_4/day or 346,75 million m^3 CH_4 per year.
As the heating value of CH_4 is considered as 10.5 kWh/m^3, this equals 3.64 TWh / yr, or 10% of the total Swiss yearly fossil NG consumption.