1. H_2 filling station

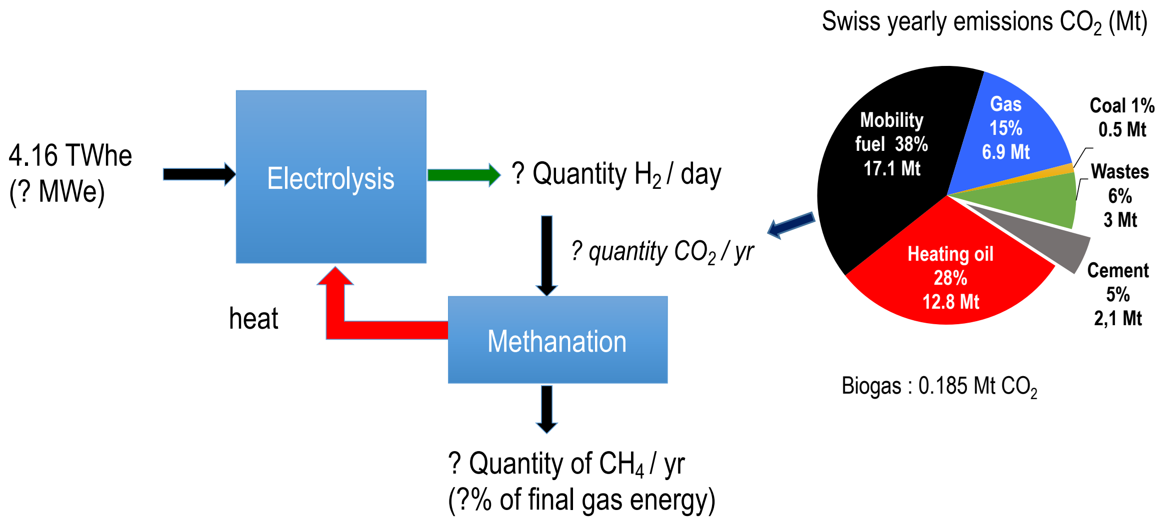
How big an electrolyser is needed to produce the daily amount of H_2 for a filling station (HRS: hydrogen refuelling station)), under the following assumptions?:

- 1000 cars/day, equivalent of 50 L gasoline/car ($LHV_{gasoline}$: 33 MJ/L)
- car average consumption : 7 L gasoline/100 km
- 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 (estimated as 9% 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. Please 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 LHV 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 : 9% 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
- Comment: this is for only 150 HRS x 1000 cars = 150'000 fillings per day. Switzerland now has 6,5 million cars. In terms of EV, there are now 7400 charging sites for 700 MW total installed power. Typical EV consumption is 18 kWhe/100 km.

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, and stored.

- Assume ~continuous operation: what is the installed electrolysis power? (MWe)
- Using 90% efficiency for steam to H_2 electrolysis, 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? (43 Mt/yr)
- 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
90% efficiency => 427,5 MW equivalence in H_2
With 120 MJ/kg, this corresponds to 427,5 / 120 = 3.56 kg H_2/s

- ⇨ *3600 s : 12825 kg/h
- ⇨ *24 h : 307,8 ton/day
- ⇨ (H_2 density 0.09 kg/m^3) : 3.42 million m^3 / day

For methanation, ¼ in volume of CO_2 is required, hence 855'000 m^3 CO_2/day or (CO_2 density 2 kg/m^3) 1.7 kt CO_2/day, which times 365 days gives 0.624 Mt CO_2/yr, about 1.5% of total Swiss CO_2 emissions. In other words, CO_2 supply for methanation would not be limiting and could come for example from the cement industry, waste incinerators, coal burners or biogas generation, where it would be relatively easier to recover.
This would generate in theory the same volume of 855'000 m^3 CH_4/day or 312 million m^3 CH_4 per year. In reality a few % are lost in conversion.
As the heating value of CH_4 is considered as 10.5 kWh/m^3, this equals 3.27 TWh / yr, or 9% of the total Swiss yearly NG consumption (~1 month).

Overall, both examples demonstrate that very large electricity generation capacity is needed, to generate/store significant amount of fuels for other/later use.