Biogas from Swiss farms

Switzerland has 57'617 farm sites, of a mean size of 20 ha per farm, spread between 1 and 50 ha for >92% of them.
40'309 farms breed cows (1'545'600 cows, 38 cows per farm on average),
8'234 breed pigs (1'584'400 pigs, 192 pigs per farms on average)
and the country has 10'519 km^2 of agricultural surface (25.5% of the total) from which also straw and other residues are recoverable.

Recoverable energy:
205 W from cow manure
40 W from pig manure
120.5 W from 1 ha of agro-waste

What is the recoverable yearly Swiss agro-biogas potential (PJ)?

- ⇨ 10 PJ from cow manure
- ⇨ 2 PJ from pig manure
- ⇨ 4 PJ from agro-residues
- ⇨ Total 16 PJ

How does this relate to the total final energy of ≈800 PJ?

- ⇨ 16 PJ = 2%

What is the average potential power-size per farm: in kW? In biogas flow (m^3/h)?
(Assume 66% CH_4 and 11 kWh per m^3 CH_4)

- ⇨ 16 PJ/yr for 57'617 farms => 277.7 GJ/yr per farm => 8.8 kW per farm
- ⇨ 8.8 kW / 11 kWh/m3 = 0.8 m^3 / h CH_4 = 1.2 m^3 / h biogas

The reality of Swiss agricultural biogas exploitation in 2016 is a production of 340 GWh in 98 installations in ICE CHP with 37% electric efficiency.
How does this compare to the theoretical energy potential ?

340 GWh = 1.224 PJ, which is 7.65% of the potential of 16 PJ

What is the average engine power size per site? (Assume 7000h load per year)

340 GWh for 98 sites = 3.47 GWh per site on average
For 7000h per year operation, the biogas energy input is : 3470 MWh / 7000h = 495.6 kW
With 35% electrical efficiency, the engine power size ≈495.6 * 37% = 183.7 kWe.

What do you conclude from this ? How could the biogas potential be better used ?

Only the very limited largest sites are exploited, as a lot of waste is needed to 'feed' an engine of a size where 'economy of scale' can be used.
We would instead be able to exploit every site with solid oxide fuel cells, which reach >50% electrical efficiency already on kWe scale.

Gasoline / Diesel replacement by inland bioethanol / biodiesel production ?

Inland mobility fuel in Switzerland is ca. 5.1 Mtoe gasoline and ca. 2 Mtoe diesel per year.

(1 Mtoe = 42 PJ)

Assume we want to replace part of it by inland biofuel production and that we can dedicate 1000 km^2 of the Swiss territory (total: 41'000 km^2) to corn plantation and 1000 km^2 to rapeseed plantation.

Bioethanol (21.3 MJ / L) from corn : 2500 L / ha

Biodiesel (33 MJ / L) from rapeseed : 700 L / ha

How much (%) of imported gasoline and diesel fuel consumption could we replace this way ?

Ethanol : 2500 L/ha * 100 ha/km^2 * 1000 km^2 * 21.3 MJ/L = 5.325 PJ
Fossil gasoline = 5.1 Mtoe = 5.1 * 42 PJ = 214 PJ
→ 2.5%

Biodiesel : 700 L/ha * 100 ha/km^2 * 1000 km^2 * 33 MJ/L = 2.31 PJ
Fossil diesel = 2 Mtoe = 84 PJ
→ 2.75%

If we were to dedicate instead 2000 km^2 of forest land (there is ca 11'000 km^2 of forest) to bioethanol production (renewable dry wood production of 20 tonne / ha.yr, converting 3 kg wood to 1 kg ethanol), how much gasoline could we replace ? (ethanol density: 0.8 kg/L)

0.333 * 20'000 kg/ha * 100 ha/km^2 * 2000 km^2 * 21.3 MJ/L / 0.8 kg/L = 35.5 PJ
→ 16.6%

If we would instead convert this yearly available wood quantity into methane (70% efficiency) for mobility (gas vehicles) ? (Assume 16.7 MJ/kg dry wood)

0.7 * 20'000 kg/ha * 100 ha/km^2 * 2000 km^2 * 16.73 MJ/kg = 46.84 PJ

Comment the results.
Wood energy is denser than energy crops for liquid biofuels (considering the land use). Gasification to methane is the most energy efficient among the considered cases. Bioethanol and biodiesel are 'easy' for exploiting marginal land areas, but can only deliver a small contribution to fossil mobility fuel replacement.