Factsheet

Natural Gas – Biogas – Power-to-Gas

Potentials, Limits, Infrastructure Needs

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Executive Summary

The goal of the Paris Agreement to avoid catastrophic climate change requires an almost complete discontinuation of the burning of fossil natural gas in Switzerland within no more than two decades. This begs the question to what extent it is feasible to replace natural gas by climate-friendly biogas or synthetic gas. In order to make biogas climate-compatible in the medium term, its greenhouse gas balance must improve significantly. In any case, domestic biogas can only provide a ninth of today's use of natural gas, even if its potential is fully exploited. Imported biogas is not an option within the foreseeable future, simply because its sustainable potential in Europe is far too low for the decarbonization of the energy sector. In addition, the Swiss customer currently does not receive the full ecological value added of biogas – but fossil natural gas with a certificate. Synthetic gases are only climate-compatible if they are produced with 100 % additional renewable electricity. The big efficiency losses in the

power- to -gas process (ptg) result in a higher cost of synthetic gas than its direct use for electricity (heat pumps, E-mobility), and require a big increase in power generation by wind and sun. Hence a reduction of the energy requirements in the buildings sector has to be achieved by the direct use of renewables (deep geothermal energy, solar thermal, wood) as well as heat pumps drawing on renewable electricity. Synthetic gas is to be used where an efficient, direct use of power is not possible. Whether or not ptg is needed for the seasonal storage of electricity is as yet not clear. Even if ptg were to be used for this purpose, it would n0t require the gas distribution system.

It must be assumed that in Switzerland the use of gaseous energy will by necessity decrease massively within a few decades. This has consequences for the owners and operators of gas distribution systems. i.e. gas providers as well as towns and municipalities: it is crucial to adjust in terms of amortization period, pricing, maintenance planning – and initiating the intelligent, regionally differentiated dismantling of gas distribution networks. If this were not to happen, the risk exposure for operators and owners of gas networks would rise enormously and the Paris climate goals would recede into the distance.

How and for what purpose do we use natural gas today?

Roughly 14% of Switzerland's final energy consumption is produced by natural gas – it comes third behind oil and hydropower[1]. While the consumption of natural gas has remained fairly constant in absolute figures (2016 roughly 36'000 GWh), its percentage of the (decreasing) total energy consumption has increased steadily[2]. Almost two thirds of natural gas are consumed for low temperature applications (heating, hot water) in households and service companies, slightly more than a third in industry (process heat). In traffic and in Swiss power generation gaseous energy carriers play a subordinate role. All natural gas in Switzerland is imported – largely from the European Union, Norway and Russia.

The Swiss pipe distribution system amounts to almost 20'000 km, excluding house service connections – the majority of which (roughly 17'500 km) are part of regional distribution systems. By international standards it is rather small (the entire German distribution network is 25 times bigger[3]). The Swiss natural gas network is not made for storing large amounts of gas: the distribution system can, as a result of pressure variability, only store 28 GWh. In addition, there are smaller day storage facilities amounting to 49 GWh storage capacity. Thus, Swiss natural gas use can be covered for a mere 18 hours. Switzerland does not have any additional big storage facilities of its own. To balance minor fluctuations and as security against supply disruption Switzerland has guaranteed access rights to the underground storage site in Etrez, France. The available storage capacity of natural gas amounts to all in all 1'510 GWh[4], which covers the Swiss use for 15 days!

How important is natural gas for climate change mitigation?

Burning natural gas produces the greenhouse gas CO_2. Natural gas has an even bigger effect on the climate when it is not burnt, transiting directly into the atmosphere, since methane has a markedly higher global warming potential than CO_2. For climate protection reasons natural gas should remain underground. Natural gas has an emission factor of 228 g CO_{2eq} per kWh final energy content if production and transport to Switzerland is taken into account[5]. Hence the specific emissions are a quarter lower than those of heating oil (301 g CO_{2eq} per kWh) and roughly nine times higher than wood pellets[6]. The use of natural gas as fuel produces about 7 million t CO_{2eq} per year, which is slightly more than a fifth of the energy-induced CO_2 emissions in Switzerland[7].

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[1] Swiss Federal Office of Energy (SFOE). Swiss Overall Energy Statistics 2016.
[2] These and the following numbers are taken from: The Association of the Swiss Natural Gas Industry. Annual Statistics 2017.
[3] *https://www.fnb-gas.de/de/fernleitungsnetze-/zahlen-und-fakten/zahlen-und-fakten.html*
[4] HSR. Speicherkapazität von Erdgas in der Schweiz. 2017
[5] According to some studies these numbers underestimate the leakage of methane during production and transport by far. In any case, natural gas produced by fracking would have a significantly higher emissions factor. *https://jeremyleggett.net/2016/05/09/an-open-letter-to-solar-companies-beware-alliance-with-the-gas-and-oil-industry/*
[6] Official 2016 life cycle assessment data by the Conference of Swiss Building administration agencies (KBOB)
[7] Swiss GHG Inventory 2017 by the Federal Office for the Environment (FOEN)

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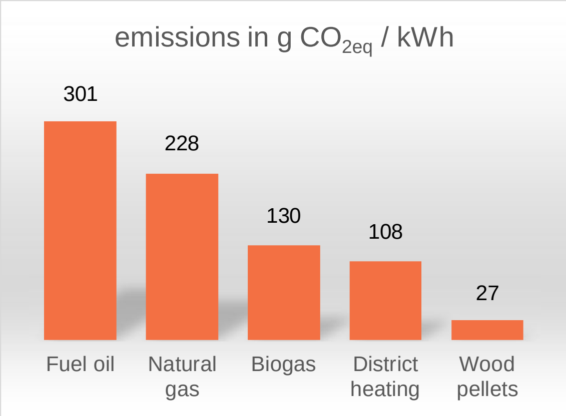
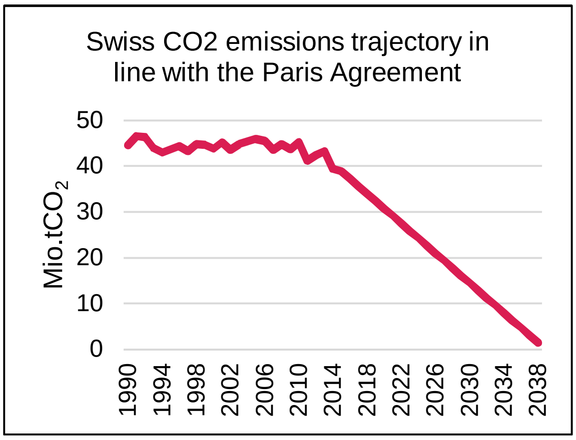


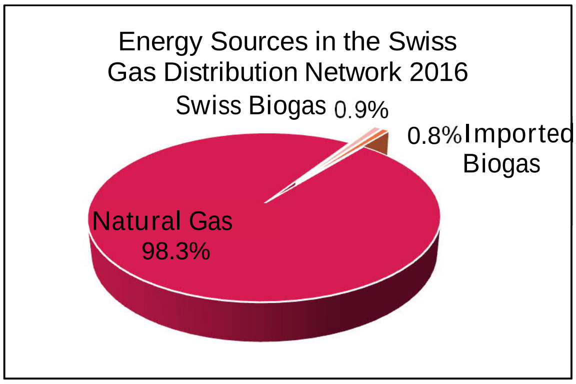
If Switzerland takes the ratified Paris Agreement seriously, it has a remaining budget of domestic net emissions of maximum 450 million tons of CO_{2eq} since its taking effect in 2016. In a linear reduction scenario Switzerland has to reduce its domestic net emissions to zero by 2038 at the latest[8]. Even if one makes less stringent assumptions so as to grant Switzerland a few more years of fossil emissions, there is no denying that the burning of all fossil fuels, and this includes natural gas, must be stopped in two or three decades. The near future means 100 % renewables and zero energy waste. The net zero might still allow for emissions - e.g. from agriculture – which as far as we know cannot be totally eliminated and therefore must be compensated by negative emissions. The uses of natural gas which are customary here – heating, hot water, industrial processes – can and must be provided without fossil energy. Especially in the buildings sector the current demand of energy can be greatly reduced, and the remaining need can be covered by renewables[9].



In a nutshell: the societally and globally accepted goal of avoiding catastrophic climate change implies, among other things, the almost compete discontinuation of burning fossil natural gas in Switzerland within two or three decades.

If there is no space for fossil natural gas in the energy providing system in the near future, there remains the question what role climate-compatible energy carriers like biogas or synthetic gas can play, and what infrastructure it needs.

What is the role of biogas?



According to the overall energy statistic of the Swiss Federal Office of Energy, roughly 1'360 GWh of gross energy were produced in the form of biogas[10]. Less than a quarter (317 GWh) was fed into the gas distribution system, the rest was turned into power and/or heat on the site of the biogas plant. As a result of the high cost the preparation and injection are only worthwhile for above average size biogas plants (in 2016 there were only 27 in the whole country). In addition to the Swiss biogas fed into the system there was practically the same amount (294 GWh) of imported biogas from abroad (mainly from Germany and Denmark). Although the feeding in of biogas as well as biogas import has shown a marked increase in the recent past, the sum total of the contribution of biogas to the entire gas supply is less than 2 %[11].

Against this background the branding 'natural gas biogas' (or even in reverse order 'biogas natural gas') with which the industry presents itself borders on consumer deception. To represent the real relationship in terms of

[8] EBP. CO_2-Budget of Switzerland. Executive Report. 2017 Or even earlier: Eckardt et al. Paris Agreement, Precautionary Principle and Human Rights: Zero Emissions in Two Decades? 2018

[9] Agora Energiewende. Efficiency First: Wie sieht ein effizientes Energiesystem in Zeiten der Sektorkopplung aus? 2017: „Reducing the primary energy consumption of buildings is of crucial importance in order to meet climate mitigation targets. "

[10] Swiss Federal Office of Energy (SFOE). Swiss Overall Energy Statistics 2016.

[11] The Association of the Swiss Natural Gas Industry. Annual Statistics 2017.

volume, 'biogas' would have to be written fifty times smaller than 'natural gas'.

Biogas from Switzerland

How much more biogas can be produced sustainably in Switzerland? It comes as no surprise that the figures vary from study to study, depending on the underlying assumptions[12]. There is a consensus on the substrate with the greatest perspective: farm manure. Taking the most recent publications into account, one arrives at a technically sustainably usable, as yet untapped potential of maximum 6'750 GWh primary energy content. Additionally, there are up to 1'640 GWh primary energy content from other sources (e.g. biogenous waste from the food industry, animal biproducts and meat processing waste, biogenous catering waste, the biogenic part of rubbish, biogenous waste from the green bin collection, as well as structure-rich biomass from traffic areas, river banks and natural protection areas)[13]. All in all, this corresponds to an additional biomethane yield from domestic substrates of just below 4'000 GWh[14]. This is a potential which, compared with today's production of 317 GWh/a, is twelve times bigger. However, it will only be possible to exploit it under optimal conditions and maximal financial support[15]. Under the current conditions small biogas plants relying purely on farm manure are not economically viable. Also, the market for the necessary co-substances like organic catering waste and industrial as well as organic waste is becoming increasingly competitive[16]. Even if almost the entire Swiss biogas potential were to be available, it could only replace a ninth of the current consumption of natural gas (36'000 GWh/a).

The gas industry set itself the medium-term goal to increase the percentage of biogas and synthetic gas to 30 % by 2030[17]. What is often neglected when setting this goal: it does not relate to the entire gas consumption, but only to the heat sector (or even only to the gas consumption by households[18]). Depending on the assumptions the plan of the gas industry still implies between 80 and 90 % of fossil energy carriers in the gas distribution system in 2030! Unless one anticipates a massive decrease in gas consumption, the renewables goal of the gas industry is totally insufficient in terms of the demands of climate protection (see above). Since the technically-ecological potentials for domestic biogas are to be seen as a long-term top limit, the industry lacks a strategy to reduce the percentage of fossil natural gas to nearly zero within the tight temporal framework of two decades.

Is Swiss biogas sustainable?

For the use of biogas as combustible there are no legal sustainability criteria (as opposed to the use as power fuel). This means that within the current legal framework it would be possible for a domestic producer to generate biogas from specially grown renewable raw material without respecting minimal standards, feeding it into the system without paying fuel duty and CO_2 tax. However, the gas industry has taken a pledge to produce biogas sustainably: it is not to be produced from specially purpose-grown raw materials; also, the raw materials are not to be in competition with food and animal feed[19]. In addition, biogas production from renewable domestic raw materials would for the time being not be economically viable without special incentives.

As regards the eco-balance of farm manure, the following applies: fermenting slurry and dung is better than not fermenting it. When farm manure is spread untreated, the highly effective greenhouse gases methane and laughing gas get into the atmosphere. Although this is taken into account in the eco-balance, biogas is by no means climate neutral (see above). In a world of zero greenhouse gas emissions a fuel with 'only' 130 g CO_{2eq} per kWh is no longer acceptable. In

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12 Steubing et al. Bioenergy in Switzerland: Assessing the domestic sustainable biomass potential. 2010.
econcept. Gekoppelte Wärme- und Stromproduktion aus Biomasse für die Schweiz: Vision – Strategie - Massnahmen. 2011.
WSL. Biomassepotenziale der Schweiz für die energetische Nutzung. 2017.

13 WSL. Biomassepotenziale der Schweiz für die energetische Nutzung. 2017.

14 With an average fermentation and processing efficiency of 45% based on econcept. Gekoppelte Wärme- und Stromproduktion aus Biomasse für die Schweiz: Vision – Strategie - Massnahmen. 2011

15 The "Energy Perspectives 2050" of the Federal Government estimates the additional biogas potential available in 2030 at 1,100 GWh/a in the most favourable scenario. The biogas sales in 2050 (domestic/imported) are estimated at 2,860 GWh/a.
Prognos. Die Energieperspektiven für die Schweiz bis 2050. 2012.

16 SBV. Praktischer Leitfaden Biogas. 2013
The fight against food waste, which is necessary for climate change mitigation, could even lead to significantly *reduced* quantities of the corresponding substrates.

17 Position paper on the Future of energy supply by the Association of the Swiss Natural Gas Industry 2016

18 Presentation by H.C. Angele on May 18, 2018

19 Biogas Principles of the Association of the Swiss Natural Gas Industry.

order to make biogas sustainable from a climate point of view, its climate balance must be improved significantly. For this purpose, the diffuse methane emissions in pre-storage, in the fermenter and the fermentation residue storage are to be avoided consistently. Over and above this, there is optimizing potential as regards energy need and CO_2 emissions during transport, storage, fermentation and post-fermentation of the substrates, as well as the processing of biogas[20].

Imported biogas

Since domestic biogas obviously cannot replace the fossil natural gas used in Switzerland, the industry focuses on the import of biogas. As it is, import already provides almost half of the biogas sold in the Swiss gas distribution system. This begs the following questions:

- What potential for sustainable biogas is there in Europe?
- How much will most likely be needed abroad, and how much will be available for export to Switzerland?
- How can it be guaranteed that the environmental benefit in terms of greenhouse gas emission reduction is completely credited to Switzerland?

The most recent study about the biogas potential in the EU was commissioned by some of the major European gas providers[21]. This has to be borne in mind when interpreting the results. The study arrives at a total European potential (disposable methane, not primary energy) of 1'072 TWh/a and 263 TWh/a of synthetic gas – all in all 1'335 TWh/a.

These figures are based on assumptions which are partly daring, as well as questionable from the point of view of climate policy and nature conservation[22]. To keep on the safe side, it is best to reduce the assumed biogas yield by 50 %. In this case biogas would only provide at most a ninth of current gas demand (4'500 TWh/a) [23] in the EU – the same as in Switzerland. Together with the potential for synthetic gas between one fifth and one sixth of the EU gas demand would be covered.

For a complete decarbonization of the energy sector the EU would have to reduce its gas consumption by 80 %. Only then some of the renewable gas potential would be disposable for Switzerland. How much renewable gas would be available for export to Switzerland at that time is totally unclear. The most plausible solution would be for Switzerland to reduce its demand for gas by efficiency and by changing energy carriers at least to the same extent as the EU.

Is imported biogas really biogas?

If biogas is fed into a local distribution network abroad, these molecules reach Switzerland only in exceptional cases. Physically fossil natural gas is imported. For the gas system, biogas can only be imported to Switzerland virtually. This means that physically natural gas is imported[24], while the importers are given a certificate which, among other things, guarantees that the corresponding amount of biogas has been fed into a foreign natural gas network[25]. If the biogas comes from Germany, the following mechanism is normally used: in case of export to Switzerland, the corresponding amount is booked off the German register, excluding the double use by another customer[26]. According to the Swiss government it is not guaranteed that this applies to other export countries[27].

Even if it were– would it be warranted that the ecological additional value added would be entirely credited to the Swiss customer? No. How much biogas is produced in Germany ultimately depends on the local frame conditions. This implies that if the biogas is exported to Switzerland after its generation, it has no effect on the German greenhouse gas balance[28].

[20] Effenberger et al. Klassifizierung der Treibhausgas- und Energiebilanz landwirtschaftlicher Biogasanlagen. 2014.
Deutscher Bundestag. Wissenschaftliche Dienste. Treibhausgasemissionen von Biogasanlagen. 2014.
Vogel. Methanverluste vermeiden. 2013.
[21] Ecofys. Gas for Climate. 2018
[22] Thus 40% (!) of the substrates are crops. In addition, sequential cropping schemes (cultivation over the whole year), which so far have only been used in Italian biogas production, are to be extended within just three decades to almost the whole of Europe (i.e. also in cooler climate zones).
On the other hand, there are various studies which - at least for Germany - even predict a decline of biogas production and in particular biogas feed-in. For an overview see:
Agentur für Erneuerbare Energien. Metaanalyse: Die Rolle erneuerbarer Gase in der Energiewende. 2018.
[23] *http://ec.europa.eu/eurostat/web/products-datasets/-/nrg_103a* - consulted on 6.4.18

[24] Accordingly, it must be declared as natural gas to Swiss customs and is subject to the relevant taxes and duties.
[25] Such a guarantee of origin should in future also be used for fossil natural gas in order to be able to trace its origin and thus, for example, exclude the import of particularly environmentally harmful shale gas (from fracking).
[26] Written information from the German Biogas Register on March 15, 2018; cf. also *www.biogasregister.de*
[27] In the case of imported biogas "neither double counting can be prevented, nor the minimum ecological requirements ensured". Swiss Federal Council. Botschaft zur Totalrevision des CO2-Gesetzes nach 2020. 2017
[28] Written information from the German Environment Agency (UBA) on May 4, 2018; as well as SFOE: Internationaler Biogasmarkt im Brennstoffbereich. 2015
The situation is different with Germany's expansion targets for renewable energies: biogas exported virtually via HKN is

Physically, natural gas is exported from Germany to Switzerland, and the same amount of natural gas is additionally exported from a foreign country to Germany. The Swiss biogas customer does not receive the full ecological value added of this biogas – but instead fossil natural gas with a certificate.

In addition, the biogas imported from Europe is lacking in European decarbonization (see below). The biogas import strategy is certainly no sustainable.

What is the role of synthetic gas?

In this paper the term ‘synthetic gas’ or ‘synthetic fuels’ means all gaseous fuels which are created with renewable power. In this chemical process often referred to as ‘power-to-gas’, renewable electricity is used to produce hydrogen by way of electrolysis. As hydrogen can only be fed into the natural gas system to a certain degree it is normally converted, together with CO_2, into methane[29]. The ptg process can be combined with the production of biogas: In the so-called direct methanisation the CO_2 in biogas is converted into methane via a reaction with hydrogen. Thus, it can be fed into the gas network with raw gas[30].

The reason why total decarbonization might need synthetic gas or fluid synthetic fuels (‘power-to-liquid’, ptl) is the fact that there is not enough sustainably produced biomass available to replace coal, oil and natural gas by wood, biogas and bio fuels[31]. The question is for what purposes and in what quantities synthetic gas can play a role technically and economically[32].

Is synthetic gas climate-friendly?

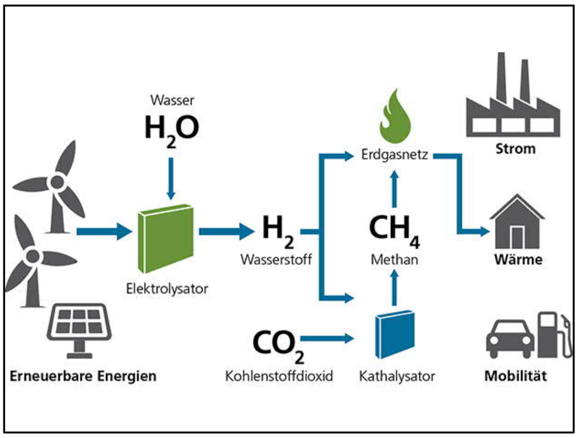
Synthetic gas is only climate-friendly if at least three conditions are fulfilled[33]:

- The power for electrolysis must come from renewable sources only.
- The power must be in excess of demand (e.g. if a wind turbine would otherwise have to be shut down) or it must be generated additionally. Otherwise we are faced with a mere shift of renewable energy from one sector to another. The surplus moved into the heat or traffic sector would then go hand in hand with a renewables deficit the power sector.
- The CO_2 required for methanisation must be captured from the air (Direct Air Capture) or produced sustainably from biogenic sources. In the medium-term fossil CO_2 is no longer an option since it would be emitted into the atmosphere eventually when combusting the synthetic fuel or it would have to be separated from the flue gas and safely stored outside the atmosphere – both with a further great energy input[34].

Ptg can never be totally climate-neutral – because of the energy input for the construction of the infrastructure and especially because of the inevitable methane emissions when generating and transporting the gas.

Can synthetic gas hold its own in the market-place?

The availability of cheap electricity during a long time span is crucial for the cost of synthetic fuels, because the higher the degree of capacity utilization, the lower the cost of electrolysis[35]. Studies show that ptg/ptl



AUS: WWW.WYNAGAS.CH

not taken into account there. Written information from the German Environment Agency (UBA) on May 8, 2018 However, whether this is also the case in all other biogas exporting countries relevant for Switzerland would have to be demonstrated.

[29] In Switzerland the hydrogen content is limited to 2 volume-percent, in Germany to 5% - prospectively this could increase to 10 to 15%.
Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018

[30] https://www.energie360.ch/de/energie-360/projekte/power-to-gas-aus-erneuerbarem-strom-wird-gas/ - consulted on 13.04.2018

[31] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018

[32] cf. e.g. Panos & Kanan. Challenges and Opportunities for the Swiss Energy System in Meeting Stringent Climate Mitigation Targets. 2018. They assume, for example, that 1,600 GWh H2 will be generated from renewable electricity in 2050, but that only 230 GWh will be fed into the gas grid as CH4 or H2.

[33] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018

[34] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018
Öko-Institut. Prüfung der klimapolitischen Konsistenz und der Kosten von Methanisierungsstrategien. 2014

[35] Agentur für Erneuerbare Energien. Metaanalyse: Die Rolle erneuerbarer Gase in der Energiewende. 2018.

plants need capacity utilization hours of at least 3'000 t0 4'000 per annum and cheap electricity to be run economically. This applies in particular to efficient high temperature electrolysers, which require constant operation[36]. But even Germany, which, compared to Switzerland, has a high proportion of fluctuating power from wind and sun, will, in the long run, not have enough disposable surplus electricity within this timespan[37]. The small amounts of locally disposable surplus power would have to be supplemented by big amounts of cheap, renewable electricity[38]. As pointed out above, this electricity must be generated additionally for ptg/ptl to contribute to climate protection. This means that ptg/ptl cannot simply rely on free excess power, but it must calculate with the full cost of additionally needed renewable electricity. It is also relevant whether or not distribution system fees are charged for the power used[39].

In addition, there are considerable costs for methanising if not only hydrogen is produced. This is particularly the case, if the necessary CO_2 comes mainly from the expensive Direct Air Capture technology and to a lesser extent from concentrated point sources (burning and fermenting of biomass). As soon as larger amounts of synthetic gases are to be produced, Direct Air Capture would have to be used increasingly because the amount of CO_2 available from sustainable biogenic sources is severely limited.

Even on the improbable assumption that power was to be free in the full load net period, generating synthetic methane still entails a substantial cost. At any rate, the cost of producing synthetic combustible and fuel is most likely to be permanently higher than the production cost of their fossil alternatives, if there is not a sufficiently high CO_2 tax[40].

How much synthetic gas can we expect?

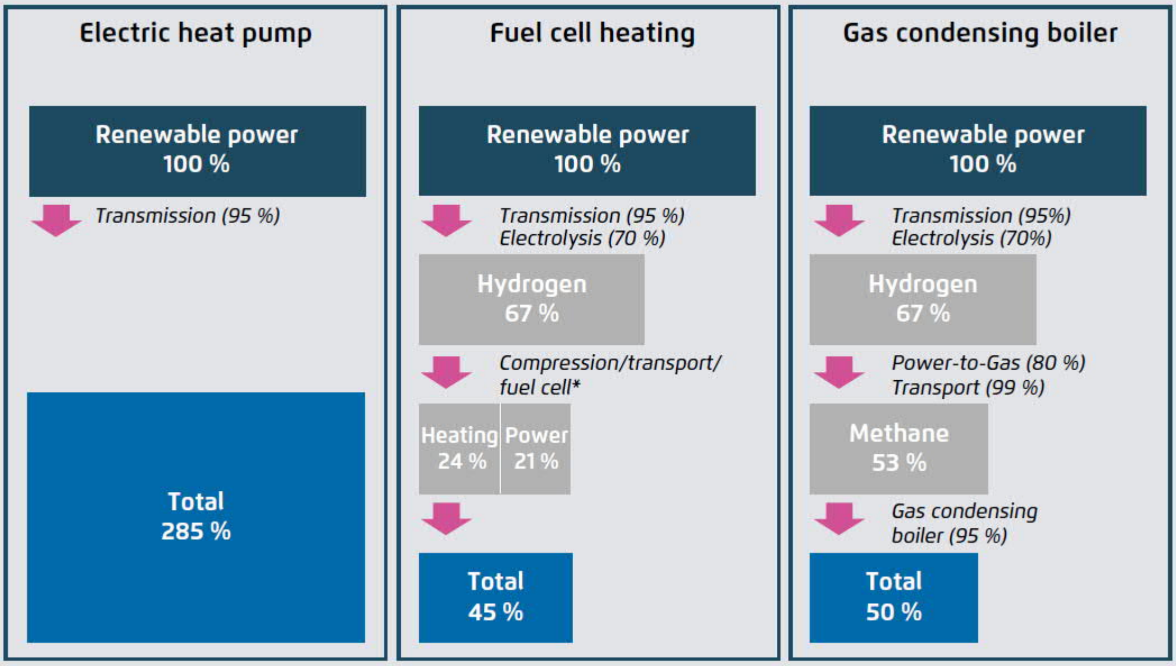
Theoretically the potential amounts of synthetic gas are huge. After all, 'only' surplus power, water and CO_2 are needed. Leaving the economic hurdles for the market viability of synthetic gas aside, the main question is how much surplus electricity would be needed: if Swiss gas consumption were to remain on today's level, (36'000 GWh), and the domestic biogas potential was fully exploited, (4'000 GWh), an additional 57'000 GWh_{el} would have to be generated to cover the remaining demand[41]. This corresponds roughly to the current power generation in Switzerland (which is far from being completely renewable). This means that in addition to the substitution of the ageing nuclear power plants, in addition to the increasing electromobility, in addition to the power consumption of more and more heat pumps (which in this scenario would also be needed to replace oil-fired heating systems), power generation in Switzerland would have to be doubled -within two or three decades[42]. These dimensions clarify that retaining the Swiss gas distribution system cannot be justified with the hope for biogas or synthetic gas.

Is synthetic gas needed in the buildings sector?

The advantage of synthetic gas (or also fluid combustible and fuel) in comparison to the direct use of power is its high energy density, its high storability and the partly already existing infrastructure - qualities which synthetic fuels share with fossil fuels[43]. However, synthetic fuels have one great disadvantage: compared to the direct use of electricity their production is fraught with high energetic conversion losses. This has immediate consequences: on the one hand, the cost of ptg (and ptl) is always significantly higher than for direct power use, on the other hand, there is a significantly higher need for power generation from sun and wind[44]. Thus only 0.56 kWh of ptg result from 1 kWh of renewable power[45].

[36] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018
Energy Brainpool (Auf dem Weg in die Wettbewerbsfähigkeit: Elektrolysegase erneuerbaren Ursprungs. 2018) contradicts this. According to them, fixed costs will fall significantly in the future and so will the relevance of high full load hours.
[37] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018
Only with a share of about 90 percent (!) fluctuating wind and solar energy there would be electricity surpluses from renewable sources in Germany during almost 4'000 hours per year.
[38] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018. In addition, ptg/ptl systems will compete locally with other, often considerably more cost-effective switchable loads such as power-to-heat, battery storage and industrial applications when using the free excess electricity.
[39] Energy Brainpool. Auf dem Weg in die Wettbewerbsfähigkeit: Elektrolysegase erneuerbaren Ursprungs. 2018.
[40] This is not contradicted by Energy Brainpool. Auf dem Weg in die Wettbewerbsfähigkeit: Elektrolysegase erneuerbaren Ursprungs. 2018
[41] 32'000 GWh ptg produced from electricity with an efficiency factor of 0,56
[42] Of course, these calculations are greatly simplified and ignore imports, for example. But as with biogas and ptg, Switzerland cannot count on unlimited import capacity from abroad for renewable electricity either.
[43] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels.2018
[44] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels.2018
[45] Öko-Institut. Prüfung der klimapolitischen Konsistenz und der Kosten von Methanisierungsstrategien. 2014

The consequences of the reduced energy efficiency along the process chain can be illustrated with the example of different heating systems powered by renewable electricity (see illustration). The highest overall degree of efficiency is achieved by the heat pump (285 %), which, as opposed to other technologies, has special leverage: it can tap environmental heat (from air, ground, water) which contains more energy than is needed by the heat pump: as a result, an energy efficiency beyond 100 % is achieved. In this example the heat pump generates an amount of heat which is three times larger than the amount of power required for the process (JAZ =3.0).



* Efficiencies: 80% (compression/transport) and 85% (total fuel cells; 45% heating, 40% power)

Note: Individual efficiencies are indicated in parentheses. Multiplied together, the individual efficiencies yield the overall cumulative efficiencies in the boxes. For heat pumps, we have assumed an annual performance factor of 3.

Next comes the natural gas condensing boiler with an overall efficiency of 50 %. At the bottom of the table is the fuel cell heating system with 45 %: whose final product is split evenly into heat (24 %) and power (21 %), the same proportion as in combined heat and power generation[46]. Hence the energy efficiency of an electric heat pump is five to six times higher than of the alternatives using synthetic gas. Clearly the degree of efficiency of electrolysis and methanisation will improve as a result of technological progress, investment and growing market penetration[47], but this assumption also applies to heat pumps.

As long as it is not clearly proven that this incontestable physical disadvantage – the lower efficiency – of synthetic fuels is compensated by advantages – e.g. by lower infrastructure costs[48] – it is obvious to first follow up all the technical solutions with fewer conversion losses – i.e. direct use of electrical energy.

In the buildings sector this means that the massive reduction of the energy demand[49], the direct use of renewables (chiefly the use of depth geothermic energy, solar thermic energy and, to a limited extent, wood) as well as the heat pump are the technologies of choice. Only if the insulation of buildings is not possible for

[46] With the electricity generated, one could also assume that (in the neighbouring house) this would be converted into heat using a heat pump with a corresponding degree of efficiency. This would increase the overall efficiency of the ptg fuel cell, for example, to approx. 84% - still three and a half times less than the overall efficiency of a heat pump.

[47] Agentur für Erneuerbare Energien. Metaanalyse: Die Rolle erneuerbarer Gase in der Energiewende. 2018.

[48] cf. FNB Gas. Der Wert der Gasinfrastruktur für die Energiewende in Deutschland. 2017. However, the assumptions on the basis of which the macro-economic advantage of a ptg scenario is justified in this study seem questionable. More than 80% of the postulated savings are due to the higher investment costs of electric cars compared to cars with combustion engines and of heat pumps compared to gas heaters. To what extent are the lower *operating* costs of direct electric use taken into account?

[49] Agora Energiewende. Efficiency First: Wie sieht ein effizientes Energiesystem in Zeiten der Sektorkopplung aus? 2017

economic or technical reasons synthetic fuels may be an alternative: either as the only energy carrier – with fuel cell combined heat and power, or in natural gas condensing boilers – or combined with heat pumps as a hybrid heating system[50]. A counterproductive outcome would be if the prospect of the use of electricity-based fuels in gas or oil boilers were to result in fewer buildings getting energetically retrofitted. This has to do with the long life cycle of buildings: only energetic retrofitting keeps all options for later decisions about the heating technology open, be it towards a heat pump or towards synthetic gas. This offers the necessary flexibility in case expectations for the future cost development are not met[51].

The uses of synthetic gas are mostly in the areas where direct use of power is not possible. This may include long-haul heavy-duty trucks, aviation and shipping, high-temperature processes in industry, organic chemical substances and possibly seasonal power storage (see below). This is in tune with many of the previous climate protection scenarios for the total energy system (esp. in Germany) until 2050[52]. From the point of view of infrastructure there are other requirements than today – partly with the consequence that the existing gas distribution network loses its most important purpose, namely providing gas for individual homes.

Is synthetic gas needed for seasonal power storage?

The argument put forward most for keeping the gas network or for setting up a ptg infrastructure is the use of excess electricity in summer and guaranteeing power supply in winter. Supraregional 'dark calms' (periods which occur mostly in winter in a great part of central Europe) must not endanger the sufficient supply of power. This will have to be taken into consideration if the electricity load in winter rises enormously due to the massive expansion of heat pumps and e-mobility, in spite of the full use of existing energy-saving potentials[53]. Excess electricity from solar and wind power plants could be seasonally stored as synthetic gas which is turned back into power in winter by gas turbine or gas-and-steam plants.

Whether or not the extreme case of a 'dark calm' over central Europe poses a real danger for the Swiss electricity supply is a controversial subject in the literature[54]. The most recent study commissioned by the Federal Office of Energy comes to the conclusion that the additional storage capacity for the residual load – i.e. the demand not covered by the disposable power generation – would be around 500 GWh maximum at a conservative estimate[55]. By comparison: the hydroelectric storage powerplants have a capacity of ca. 9'000 GWh[56]. Compared to the current storage potential only a small expansion will be required in the medium term.

Ultimately it is not clear to what extent Switzerland will need other seasonal power storage plants. What is clear, however, are the preconditions for infrastructure if ptg were to be the preferential option. And they are often forgotten: what is not required is the gas network since it has hardly any storage capacity (see above), and because, for economic reasons the ptg process as well as the reconversion into electricity must take place in bigger, more centralized units. However, a sufficient number of big gas storage plants would be required (of which Switzerland has only a very limited number at the moment) as well as a few gas turbines connected to the remaining grid and/or gas-to-steam power plants[57]. The entire infrastructure would have to be cost-effective with very few full load hours, as its full capacity will only be required in a European 'dark calm' situations.

[50] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018
However, heating a poorly insulated existing building without further insulation with 100 percent synthetic fuels is likely to become very uneconomical in the long term - especially if demand from wealthier sectors causes ptg/ptl prices to rise.
[51] Agora Energiewende. The Future Cost of Electricity-Based Synthetic Fuels. 2018
[52] Agentur für Erneuerbare Energien. Metaanalyse: Die Rolle erneuerbarer Gase in der Energiewende. 2018. „While all studies with ambitious climate mitigation targets agree that ptg is indispensable as a flexibility option in the electricity sector, the greatest potential for ptg is seen in transport and industry "(translation by WWF Switzerland)
[53] SATW. Die Rolle von dezentralen Speichern für die Bewältigung der Energiewende. 2016
However, this in particular would necessarily be linked to low gas utilisation in the buildings and transport sector and the corresponding need for decommissioning the gas network....
[54] For an overview of various studies, see the Swiss Environmental Alliance's factsheet on security of supply
[55] BfE. Modellierung der System Adequacy in der Schweiz. 2017
[56] SATW. Die Rolle von dezentralen Speichern für die Bewältigung der Energiewende. 2016
[57] CHP systems also play a secondary role here, because in addition to electricity, they produce low-temperature heat, for which other solutions are more appropriate (see above) - not least because the heat would only be available in a few hours per year.

Conclusions: what is the future of our gas infrastructure?

According to the present state of knowledge and the scenarios for the immediate future, the consumption of gaseous energy carriers will have to decrease sharply within the space of few decades. Only in this manner does the gas supply system make its requisite contribution to the common goal of avoiding a dangerous climate crisis. The reduction of gas consumption would have to be around at least 80 % if one considers the limited potential for domestic and imported biogas as well as the uncertain perspective for ptg.

This has significant consequences for the infrastructure required. On the one hand quantitively, because they will be only marginally used. On the other hand, qualitatively, because various elements, (e.g. regional distribution networks) are most likely to be even less required than others (e.g. long-distance transport pipes or storage plants). Regardless of where and how fast today's consumption will decrease, adjustments are required as regards amortization periods, pricing, maintenance planning – and setting up an intelligent, regionally differentiated dismantling plan. If this is not done, the risk exposure of the operators and owners of gas networks, i.e. the gas providers as well as towns and municipalities, will increase substantially. Additionally, the question of adjusting the gas distribution system in a climate-friendly manner may turn into a question of legal compliance as soon as all the legal consequences of the Paris climate agreement are implemented on a national level. For certified "Energy Cities" (European Energy Award for cities) and other municipalities which strive to be ecological models it is already crystal clear: the communal gas infrastructure plan must no longer ignore the demands of climate protection.

The management and the board of most gas providers overlook this problem out of ignorance or fear. Now there still would be solutions: it is crucial to stand squarely behind one's own contribution to combatting climate change, to collect and acknowledge the necessary facts and to draw the entrepreneurial consequences unencumbered by prejudice.

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