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Power to the People
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Energy and Biomass

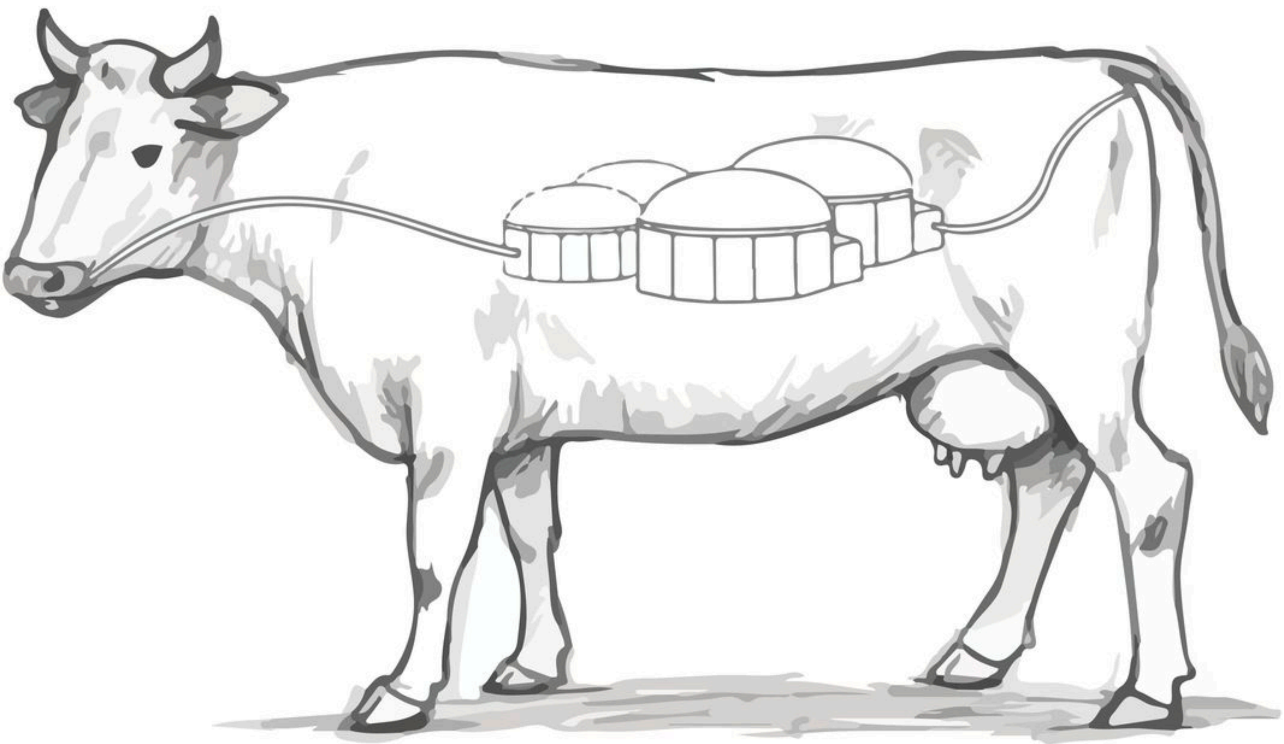
Fermenting Contradictions: Can We Rehabilitate Biogas as a Green Energy?

Nicolas Schenkel, Mischa Engeler, and Nicola Nussbaumer

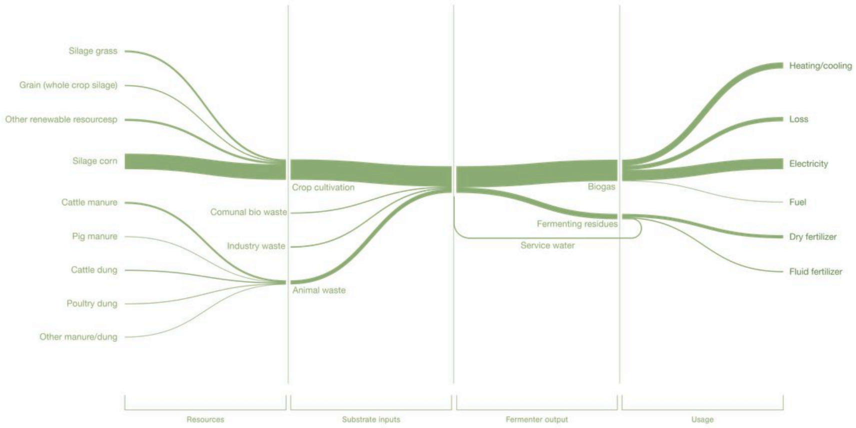
Between wind turbines, solar farms, and the vast lignite mining pits, biogas plants in the Rheinland often go unnoticed. Yet most of biogas energy production is directly tied to agriculture, a field that has been actively shaping the landscape for thousands of years. The farmers running biogas plants today are entrepreneurs. Their choices and obligations determine the character of biogas energy as a whole.

The contradictions between this useful and—in light of the recent gas crisis—perhaps indispensable renewable energy and its real-world failings stand at the centre of this work. By virtue of three distinct case studies the reportage illustrates the current state of agricultural biogas production in the region. The findings from these case studies evoke a vision of biogas's role within a more ecological model of agriculture, exemplified through the commune of Nörvenich.

Biogas Production – It Works Like a Mechanical Cow



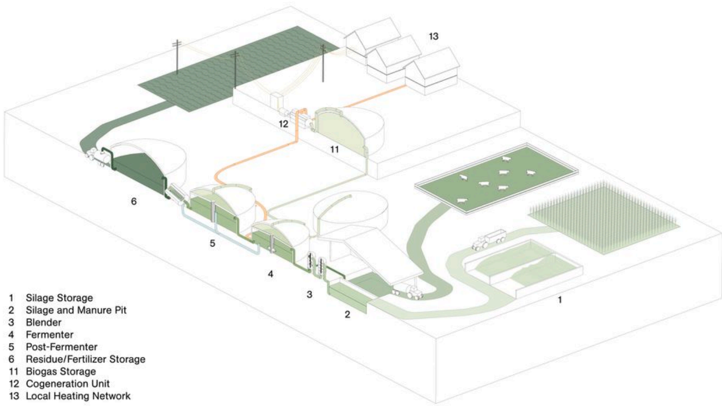
A cow's digestion relies on bacteria and other microbes to break down fodder into usable energy. This process, called anaerobic fermentation, is the same that extracts biogas from a variety of organic substrates in a biogas plant. Due to the direct availability of such substrates, the agricultural sector has been a key driver in the development of the technology. But how exactly does a typical biogas power plant operate within the field of agriculture?



AGRICULTURAL BIOGAS METABOLISM GERMANY
Source: German Environment Agency (UBA) [https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#ueberblick], Fachagentur Nachwachsende Rohstoffe [https://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biogas.html]

Its fertile loess soils have secured the Rheinland its role as an agricultural hotspot throughout history. Correspondingly, agricultural biogas plants account for the majority of energy production from biogas in the region. These plants use the energy stored in agricultural produce and waste products—so-called substrates—to generate heat and electricity.
Despite criticism regarding the ethical implications of using arable land to grow energy crops instead of food, silage corn remains the most commonly used substrate due to its high energetic potential. In North-Rhine Westphalia, silage corn cultivation took up one fifth of all arable land in 2021. Yet silage corn is not only used as a substrate but also as animal fodder. Nowadays, other forms of silage like the cup plant, *Silphium perfoliatum*, are also explored as a possibility to reduce monocultural corn farming for biogas.

Through a change in subsidy distribution, the German government has been able to increase the amount of manure and animal dung used in biogas plants since 2014. Evidently, producing energy from waste is more socially and ecologically desirable than using valuable farmland for energy crops. However, the manure and dung supply that biogas production currently relies on is ensured mainly by large-scale animal farming with its questionable animal welfare standards and high greenhouse gas emissions.

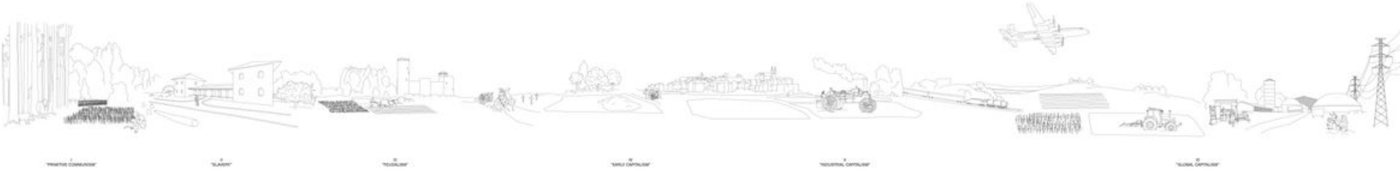


BIOGAS PLANT MODE OF OPERATION

At a typical biogas plant that uses both renewable agricultural produce and animal waste, the substrates are mixed at the start of the production process. The resulting sludge then enters the fermenter, where bacteria work in a heated environment to perform anaerobic fermentation. During this multi-stage process, the microbes break down the organic matter and—as an end product—create biogas. The biogas yield may be increased by using a post-fermenter to continue the process. After fermentation the biogas is stored. The substrate itself exits the fermenter as a wet mixture known as digestate. This substance is rich in nutrients and can be deployed as fertiliser. Usually, agricultural biogas plants utilise cogeneration units to render the energy usable. The gas is burned in combustion engines which drive alternators to produce electricity. Waste heat from the combustion is already often used to heat the fermenters and surrounding buildings. But while the produced heat frequently exceeds the demand of the plant itself, using it in local heating networks proves too large of an investment for most biogas producers.

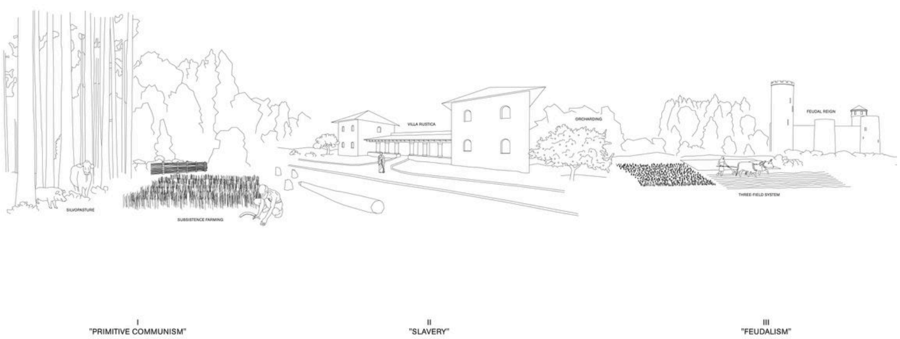
From Peasant to Producer – A History of Agricultural Change

Evidently, biogas production has not always been part of agriculture. The farmer as energy provider is only one symptom of a long process that has alienated agriculture from its originally singular purpose of feeding people. Ingrained in the logics of a global market, farmers today develop various strategies to subsist in spite of economic pressure.

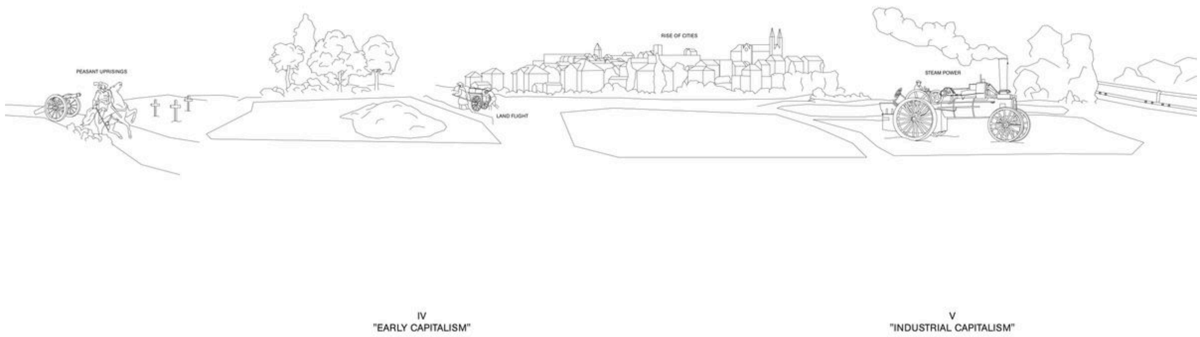


Around 5,000 BC, the neolithic revolution reached the Rheinland. Early agriculturalists, pertaining to the so-called Linear Pottery Culture, migrated from Southeast Europe following the distribution of highly fertile loess soils. They brought with them the cultivation of grains like emmer and barley as well as domesticated cattle, goats, sheep, and pigs. But with the emergence of a more sedentary way of life came also private property and its unequal distribution.
While idealising the early agricultural communities as self-sufficient and equitable is thus too short-sighted, the yields at the time did not enable much of a functional division of society.
This began to change already with the improvement of ploughs in the Iron Age but asserted itself clearly with the arrival of the Romans, who began colonising the region around the beginning of the common era. The land surrounding the villae rusticae—the Roman manors—was cultivated by slaves and leaseholders, the latter of which soon made up the majority.

In the Middle Ages, Feudalism developed from the remnants of Roman and Germanic agricultural traditions. Control over entire peasant families and the promise of military protection guaranteed stable conditions for landlords. With substantial extensification of agricultural surface through wood clearing and certain technical and procedural innovations—such as the emergence of the three-field system—this period saw a rise in yields and a steady population growth. When this growth ended with the Black Death and other epidemics, agriculture—and with it the feudal system—fell into deep crisis. Feudal lords tried to compensate the decline of their wealth and power by intensifying the pressure on their serfs. This led to a series of peasant uprisings that were violently beaten down.

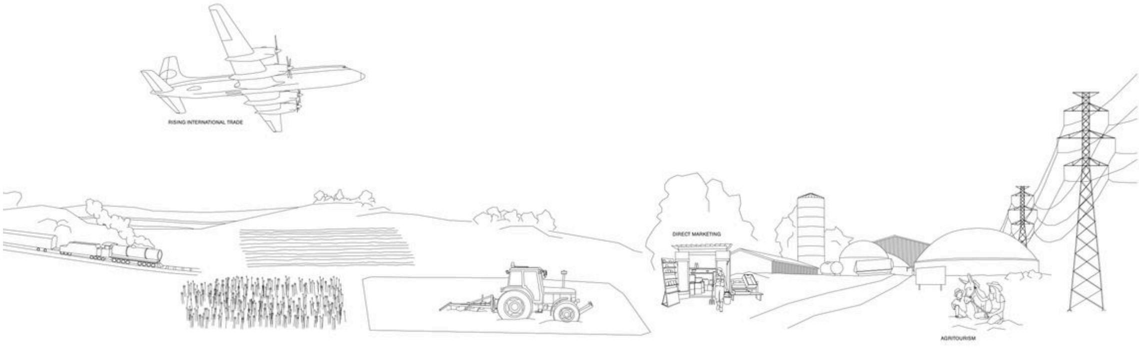


The end of the feudal system only came about with the rise of the bourgeoisie and the cities, culminating in the French Revolution. Both humanist tendencies and the declining profitability of feudal reign led to the liberation of peasants. However, this liberation also meant the exposure to the logics of capitalism.
As farmers began producing for the good of their own families, the importance of increasing yields rose again. This development was accelerated by the emergence of industrial technology within agriculture. But steam power and scientifically improved seeds and fertiliser meant significant investments, favouring the larger farms that often stayed in the hands of established property owners.



With the transition to an industrial society, the role of agriculture declined. The amount of Germany's population working in agriculture plummeted from 42.5% in 1882 to 28.6% in 1907. At the same time, technological innovations in transport and communication fuelled international trade. An international division of labour established itself, wherein German farmers could not compete with cheaper foreign produce, for instance from Russia. Concurrently, laissez-faire trade policies guaranteed no protection by import tariffs.

After the rupture of the two world wars, the redevelopment of agriculture in the Federal Republic was tied to the economic system of social market economy. While state support could somewhat moderate pressure, the continuing intensification of industrial production was not easily accounted for in agriculture. To keep up with the growth the rest of the economy experienced, farmers had to increase the use of mineral fertiliser and pesticides, abandon a holistic approach to agriculture in favour of specialisation, or simply increase the size of their farms.
For farmers incapable of adapting to the market's needs, the primary role of food supplying became less and less cost-effective. Thus, the more recent history of farming is one of diversification. The agricultural landscape of today is also one of recreational spaces, agritourism, specialised direct marketing, and energy production.



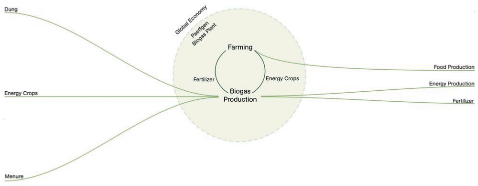
VI
"GLOBAL CAPITALISM"

Paeffgen Biogas GmbH – Biogas Made Profitable

Edmund Paeffgen runs one of the largest biogas plants in the Rheinland. He is convinced that biogas can fulfil an important role in a renewable future. But according to Paeffgen, efficient biogas production can only succeed with full dedication and expertise.

PAEFFGEN BIOGAS PLANT

Leftovers from ethanol production were at the origin of Edmund Paeffgen's occupation with biogas. Paeffgen opened his power plant in 2005, when subsidies had been raised and biogas production became profitable for the first time. Soon, his plant was much more than a useful form of waste disposal. Paeffgen saw the potential of providing energy from the land and began to expand his power station. Nowadays, it consists of six fermenters and post-fermenters and six cogeneration units able to output a total of 4,300 kW_{el}. While the biogas plant runs without much manual labour, it requires constant surveillance. Thus, Paeffgen has three employees that help him ensure a frictionless operation throughout the year. In addition to profound knowledge and attention to detail, running a power plant of this size requires a substantial amount of substrate.



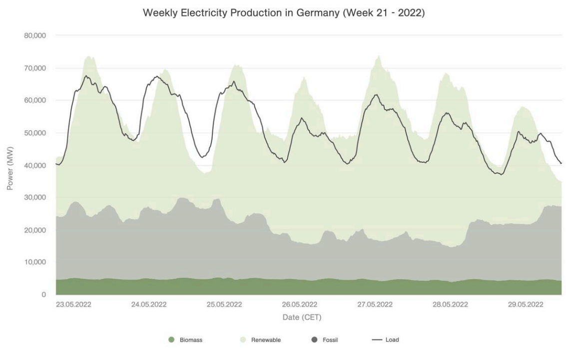
BUSINESS MODEL PAEFFGEN BIOGAS

CATCHMENT AREA PAEFFGEN BIOGAS

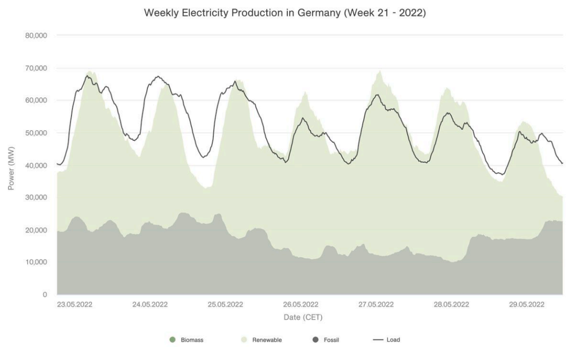
Farming and biogas production are two largely separate businesses for Paeffgen. On his 310 ha farm, he grows mostly grain and sugar beet, which he sells into food production, and a small portion of the silage corn he uses in the biogas plant. The rest of the silage corn—which makes up about 55% of his substrates—stems from 24 different farms in his vicinity. To decrease the amount of energy crops used, Paeffgen also ferments manure from surrounding farmers. Additionally, he buys chicken dung from large-scale poultry farms in the Netherlands. The highly specialised animal farms profit doubly from deals with biogas plants since they would otherwise have to pay for proper disposal of the dung.

Paeffgen utilises the process heat from his cogeneration units to keep his fermenters at the appropriate temperature, heat the buildings on the plant and in its surroundings, and even to dry part of the digestate left after fermentation. This high-quality fertiliser is then sold throughout Europe and even as far as the United Arab Emirates. Finally, the generated electricity is fed into the grid.

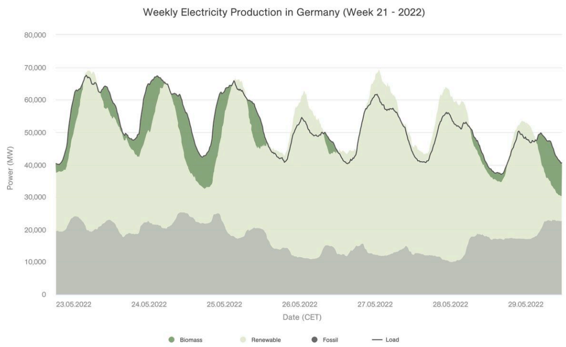
In order to be financially lucrative, Paeffgen Biogas GmbH still requires the high biogas output of silage corn as well as dung deliveries from Dutch animal farms. The spread of silage corn cultivation has been widely criticised due to its impact on biodiversity and the surface it takes away from food production. Concerning the animal waste, the long transport distances make for high greenhouse gas emissions and the farming practice itself relies on high volumes of fodder, impacting biodiversity and causing an oversaturation in nutrients that harms the soil quality over time. But biogas production at a large scale also has its advantages.



Current Weekly Electricity
Production in Germany.
Source: Energy-Charts.info [https://energy-charts.info/charts/power/chart.htm?l=de&c=DE&week=21]



Current Weekly Electricity Production
in Germany without Biomass.
Source: Energy-Charts.info [https://energy-charts.info/charts/power/chart.htm?l=de&c=DE&week=21]



Current Weekly Electricity Production in
Germany with Biomass as a Regulator.
Source: Energy-Charts.info [https://energy-charts.info/charts/power/chart.htm?l=de&c=DE&week=21]

At the moment, electricity from biogas plants enters the grid relatively evenly, similar to how most fossil power plants operate. But this goes against the great advantage of biogas. While the main renewable energies in Germany—wind and solar—evidently depend on weather phenomena, biogas can be stored. Storage of biogas in tanks and of solid biomass before fermentation allows the flexible production of electricity according to the needs of the consumers. With the phasing out of coal power and the further expansion of renewables in Germany, this quality becomes more and more crucial for a stable electricity supply. However, biogas plants need to go through a process called flexibilisation to make the adaptation to the market possible. Flexibilisation usually entails the addition of further cogeneration units and the expansion of gas storage to make high momentary power outputs possible. For Edmund Paeffgen, it is a key component of adapting biogas energy production to a renewable future.

PAEFFGEN BIOGAS PLANT

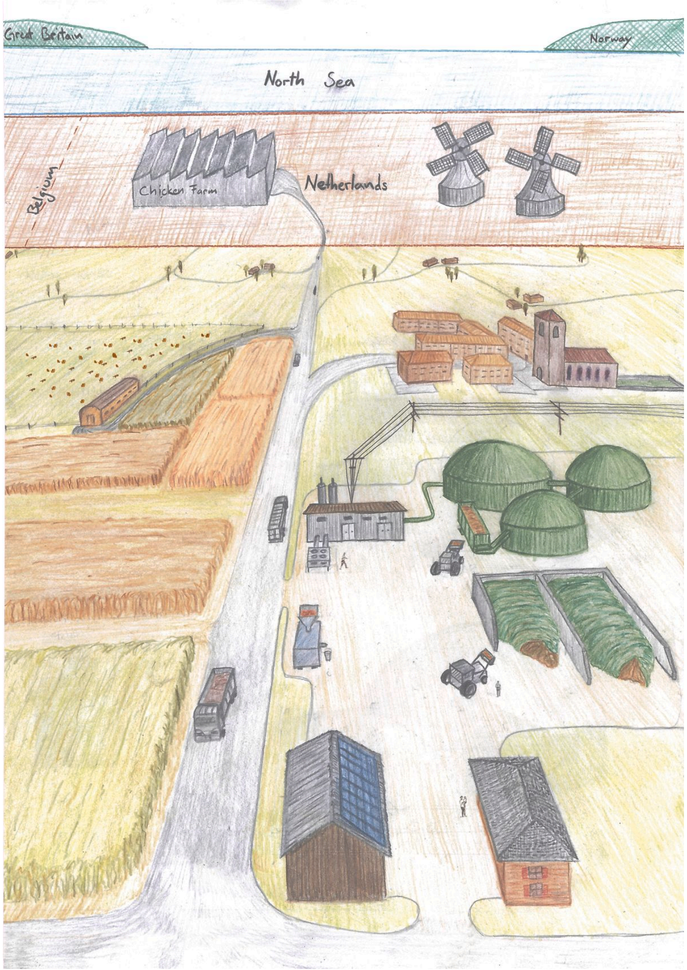
BIOGAS FERMENTERS

COGENERATION UNIT

SILAGE CORN AND BIOGAS STORAGE

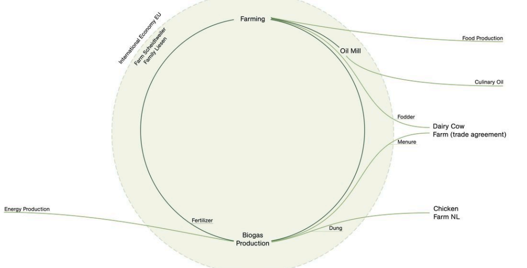
Scheidtweilerhof – Biogas as a Diversification Strategy

Gottfried Liesen and his family decided to invest in a biogas plant in 2011 to help compensate low prices on the German crop market. However, biogas has proven to be a volatile source of income as well. The evolution of subsidies has very direct implications on both farming and biogas production.



SCHEIDTWEILERHOF

When the Liesen family built their power plant, they did it mainly for financial stability. Prices for agricultural produce were too low for small and medium-sized farms like Liesen's Scheidtweilerhof to compete against imported goods. Enabled by almost insignificant transport costs, crops from countries with lower wage levels and ecological standards dominated the market. In this environment, the stable income from subsidies on biogas energy was a welcome option for many farmers. But with frequent changes in legislation, the subsidies did not prove to be as reliable after all. Apart from biogas, the Liesen family have also diversified their agriculture, invested in an oil mill, and ventured into direct-to-consumer marketing to be less dependent on distributors.

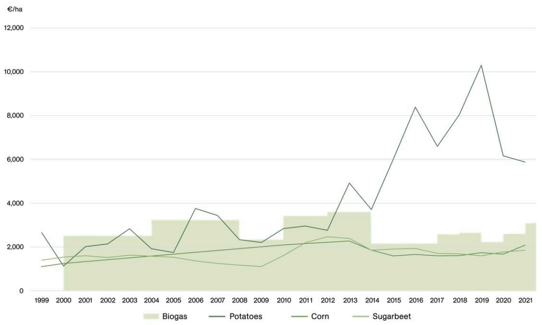


BUSINESS MODEL SCHEIDTWEILERHOF

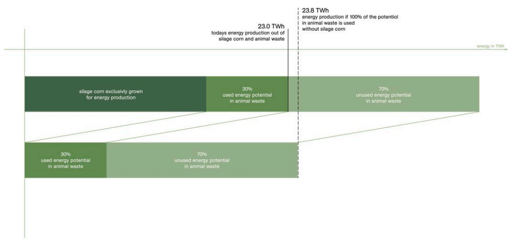
CATCHMENT AREA SCHEIDTWEILERHOF

Despite the economic pressure, the Liesens remain devoted to agriculture and the role of the farmer as food provider. On 240 ha they grow 15 different crops, from the traditional Rhinish crop rotation of wheat, barley, and sugar beet to potatoes and corn. Most of the produce is directly sold into food production. Since 2022, the Scheidtweilerhof has its own oil mill, where the family produces edible oils from rapeseed, sunflowers, hemp, and linseed. The oils are sold both directly to consumers and in supermarkets and farm shops in the region. For substrates, the Liesen family use silage corn, manure, and dung. The corn is both grown on the Scheidtweilerhof itself and bought from other nearby farms. For manure, Gottfried Liesen has found an agreement with a dairy cow farm which he supplies with fodder in exchange. Additionally, the Liesens also import dung from the Netherlands.

On the Scheidtweilerhof, the digestate is used as fertiliser for crop cultivation. The cogeneration unit can output up to 500 kW_{el} of power. Process heat is used to heat the fermenters and the buildings on the farm. Gottfried Liesen is also considering investing in a local heating network to make use of all the excess energy. Electricity is fed directly into the grid.



RENEWABLE ENERGY LAW (EEG) SUBSIDIES COMPARED TO PRODUCE PRICES.
Source: de.statista.com [https://de.statista.com/] bioenergie-branche.de [https://www.bioenergie-branche.de/wirtschaft/recht] next-kraftwerke.de [https://www.next-kraftwerke.de/wissen/anzulegender-wert#anzulegender-wert-fr-biogas-und-biomasseanlagen]



POTENTIAL IN ANIMAL WASTE IN GERMANY.
Source: Federal Environment Agency UBA [https://www.umweltbundesamt.de/themen/biogasproduktion-aus-guelle-bioabfall-ausbauen#:~:text=Aktuell%20werden%20nur%20rund%2030,hat%3A%20Treibhausgasemissionen%20der%20G%C3%BCllelagerung%20bzw.]

In Germany, subsidies on biogas production are regulated in the Renewable Energy Law (EEG). When the Liesens took up production, subsidies on electricity from biogas lay at a fixed rate of 20 ct./kWh, covering the costs for substrates and creating some profit for the farm. Since all biogas plants were subsidised equally, most farmers relied mainly on silage corn and other energy crops to maximise gas volumes. With the emergence of more and more agricultural biogas plants, criticism towards the large-scale cultivation of energy crops arose. Under the phrase Food versus Fuel, the ethics of growing plants solely for energy production in light of world hunger have been widely debated. Acknowledging this, the German government adjusted the EEG in favour of using waste products to produce biogas. In reaction to this, many farmers started to substitute part of their silage corn with dung and manure. While the increased support for biogas plants working with animal waste appears ethically and ecologically sensible—especially considering around 70% of the potential in manure and dung is still not used in Germany—the frequent changes in the legislation make it difficult for producers to navigate the EEG. Currently, the EEG is being worked over to get rid of the regulatory flaws within. There is not enough political involvement to create new incentives to support the actual qualities that biogas has like the storage capacities.

SCHEIDTWEILERHOF

BIOGAS FERMENTER AND DUNG PILE

COGENERATION UNIT

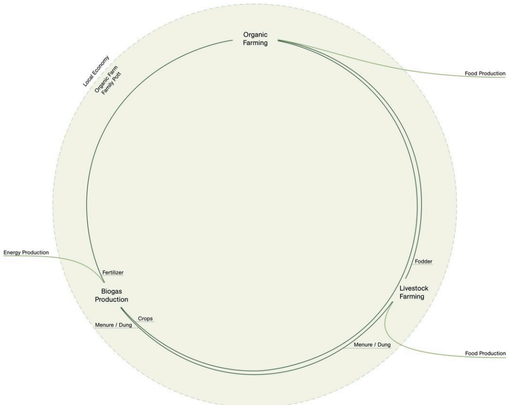
SILAGE CORN AND DUNG STORAGE

Gut Marienhof – Biogas and Organic Farming in Harmony

For Christoph and Anne Pott, their biogas plant has become a helpful tool in adopting a more circular mode of farming. When economic growth is not the primary target, energy from waste shows its benefits for agriculture and the environment. But from an energy perspective, the more sustainable model entails an efficiency deficit.

GUT MARIENHOF

The Pott family made the decision to take up organic farming after experiencing water shortages in 2018. The very direct realisation of agriculture’s dependence on functioning ecosystems was to them a call to reduce their impact on the environment. Together with their farming, the Potts also adjusted the operational mode of their biogas plant to be more ecological. To them, this transition confirmed that biogas production can be beneficially used within organic agriculture. At Gut Marienhof, the power plant acts as a relatively low effort form of waste disposal and closes nutrient cycles.

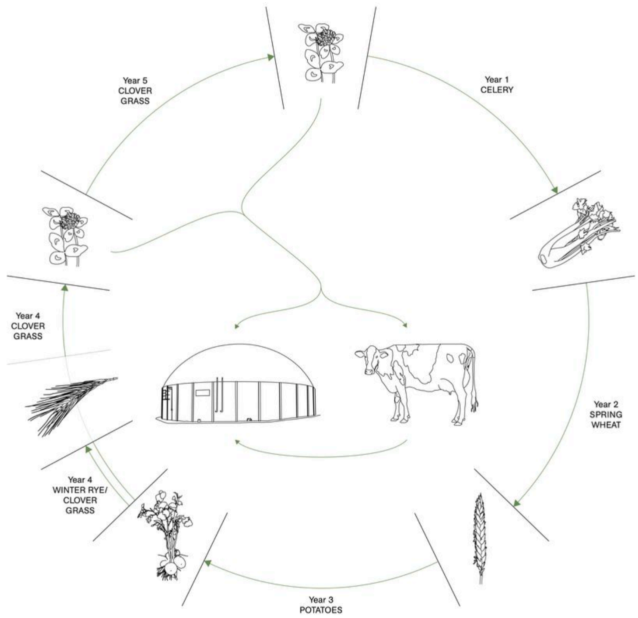


BUSINESS MODEL GUT MARIENHOF

CATCHMENT AREA GUT MARIENHOF

The Potts practise both cattle farming and crop cultivation under organic standards. On 70 ha, they grow wheat, corn, clover, and a range of vegetables. The clover is a necessary addition for cultivation to work without synthetic fertiliser. In addition, it also serves as fodder for the cattle and as one of the substrates the Potts use for biogas production. To that end, they also collaborate with other organic farmers in the region, who deliver their clover to Gut Marienhof for fermentation and receive digestate as fertiliser in exchange. Furthermore, the Potts also collect and ferment their cattle dung.

The produced electricity is again fed into the grid. While the cogeneration unit at Gut Marienhof technically has a power output of 500 kW_{el}, the Potts are unable to generate the same gas volumes as the Scheidtweilerhof. Clover fermentation produces only about two thirds of the gas per growing area that silage corn does. In addition, most of the process heat from the Pott family's cogeneration unit is unfortunately lost at the moment since a heating network is too expensive.



ORGANIC FARMING CROP ROTATION
Source: Oekolandbau.de
[https://www.oekolandbau.de/landwirtschaft/pflanze/grundlagen-pflanzenbau/fruchtfolge/]

In organic crop cultivation, the prohibition of synthetic fertilisers—such as ammonia or nitrates—demands other strategies to replenish nutrients in the soil. One such strategy is the introduction of legumes into the crop rotation. Legumes like clover are able to bind nitrogen from the atmosphere. To release the nitrogen into the soil, they are traditionally left on the field when it is overturned. However, for animal breeding farms, the clover can also function as fodder. With the biogas plant, the Pott family is able to use both benefits of clover. They ferment the excess clover as well as the cow dung. And, when the cattle do not finish their fodder, the biogas plant can take care of it. Even for farms without livestock, fermenting the clover makes sense since the fertilising nutrients remain within the digestate.

Clover and other legumes enter a very harmonic relationship with biogas production within the context of organic farming. But for many organic farms, the amount of legumes and other waste products is too small to make biogas production a worthwhile investment.

GUT MARIENHOF

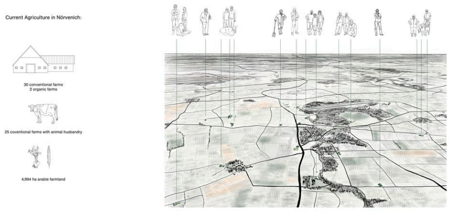
BIOGAS FERMENTER AND STORAGE

COGENERATION UNIT

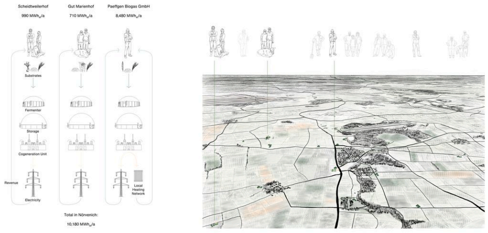
CALF STABLE

Towards a Landscape of Biogas Cooperation

Breaking out of the constraints of an industrialised agriculture, a cooperative network of producers embraces the specific qualities biogas offers. By supporting the other renewable energies and granting waste products a purpose, biogas gains a new position in society. And perhaps, this cooperative system can help farming return into the public consciousness.



CURRENT AGRICULTURE IN NÖRVENICH
Source: Information and Technology North Rhine-Westphalia
[https://www.it.nrw/agrarstrukturerhebung-2016-statistiker-befragen-40-000-bauern-nrw-10221]

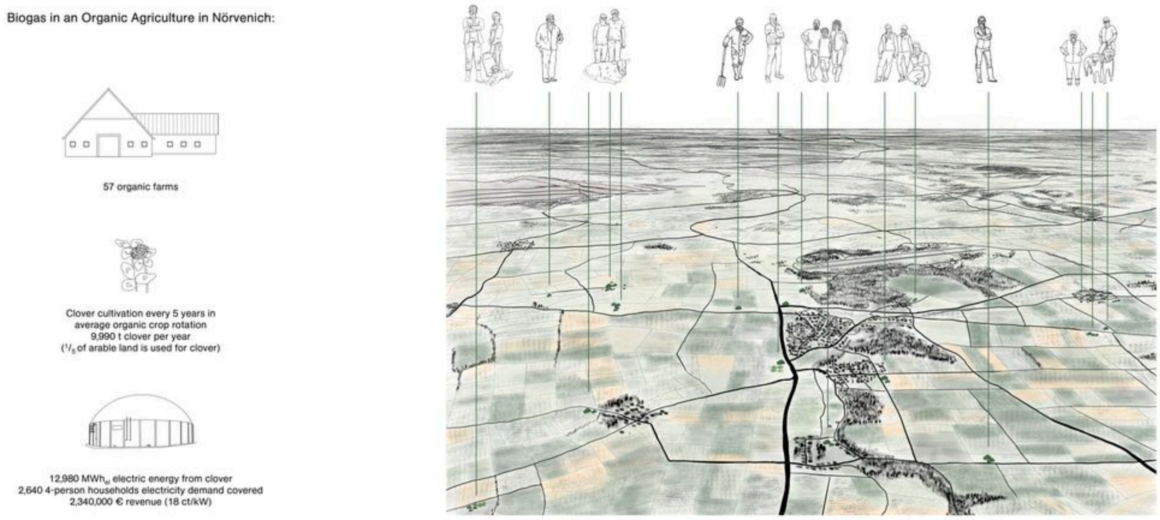


ESTIMATED CURRENT BIOGAS PRODUCTION IN NÖRVENICH

The Rheinland's agricultural biogas production today is far from sustainable. Ecological and economic concerns are at an imbalance. The case studies analysed in this work showcase how a globalised agricultural market and political sluggishness have shaped a landscape of detached biogas islands scattered across the vast fields of industrialised farming. Despite their confrontation with the same milieu, biogas plays a different role for each of the producers.

Under the imperative of growth—be it economic or energetic—biogas production relies on large amounts of highly generative substrates. But monocultural silage corn cultivation and large-scale animal farming come with a range of ethical and environmental implications. When angled towards ecological production, the implementation of energy from biogas shows efficiency problems. In addition, infrastructure improvements are often financially unattainable to smaller producers.

The main hurdles on the way to sustainable biogas production in the Rheinland are deeply rooted in present-day agricultural practice. Synthesising the discoveries made throughout this work, a schematic proposal for the integration of biogas into a more ecological mode of farming manifests itself in the context of the Rhinish commune of Nörvenich.

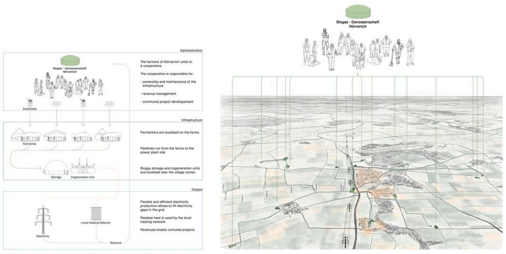


PROPOSED ORGANIC BIOGAS PRODUCTION IN NÖRVENICH

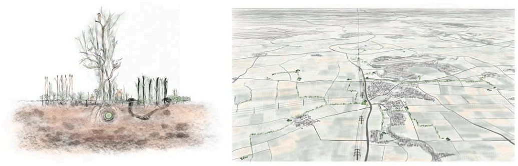
nder the generous assumption of a complete transition of Nörvenich's agriculture to today's organic farming standards, the output currently generated by the three case study power plants could potentially be ensured with clover alone. Looking beyond clover or considering a more realistic scenario of agricultural reform, the amount of available substrates should be even higher. However, the aim of this proposal is not to maximise power output but to find a sensible model for biogas, taking ecological and social questions into account in addition to technical ones.

From a technical standpoint, the central idea is a network of smaller fermenters connected to centralised cogeneration units by biogas pipelines. Decentralised fermentation promises reduced transport distances while a large, concentrated storage and power plant enable an efficient and flexible use of the gas. In Nörvenich, the existing infrastructure of Paeffgen Biogas GmbH could serve as the central plant. Its location right on the edge of the most populous village in the commune makes distributing the process heat quite efficient.

To enable more farmers to join the network, it could be organised as a cooperative.



PROPOSED BIOGAS COOPERATIVE



BIODIVERSITY STRIPS

Forming a cooperative would decrease the financial hurdle of the infrastructure developments necessary to enable widespread fermentation of waste. Loans could be obtained more easily and the organised group of producers could have more of an impact on local politics. In the proposal, all biogas production infrastructure is owned by the cooperative and the profits from heat and electricity sales are distributed through its administration. While covering costs is an aim, increased revenue is not what should attract farmers to the system. Rather, the cooperative gives them the opportunity to steer profits towards communal projects with the aim of reconnecting the ties between agriculture and the rural population.

Farmers markets, common meals, or cultural events offer opportunities for the residents of Nörvenich to become aware of a previously inconspicuous form of energy production. In addition, the cooperative funds environmental projects. Biodiversity strips covering the pipeline network help introduce a more fragmented and rich agricultural landscape.

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