



IEA Bioenergy
Technology Collaboration Programme



Integration of biogas systems into the energy system

Technical aspects of flexible plant operation

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Webinar:
Flexibility Provision from Biogenic Gases
23th of November 2022

Rytec

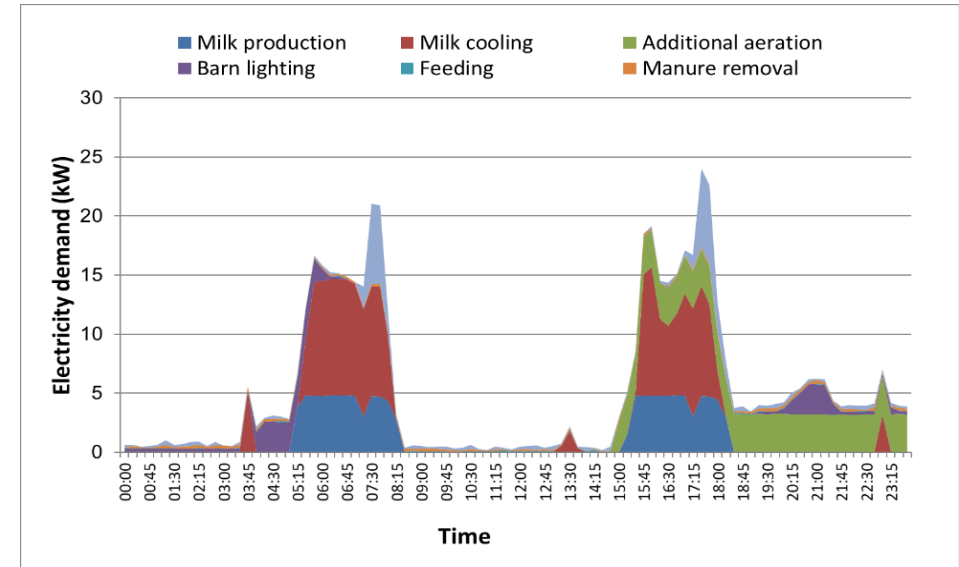
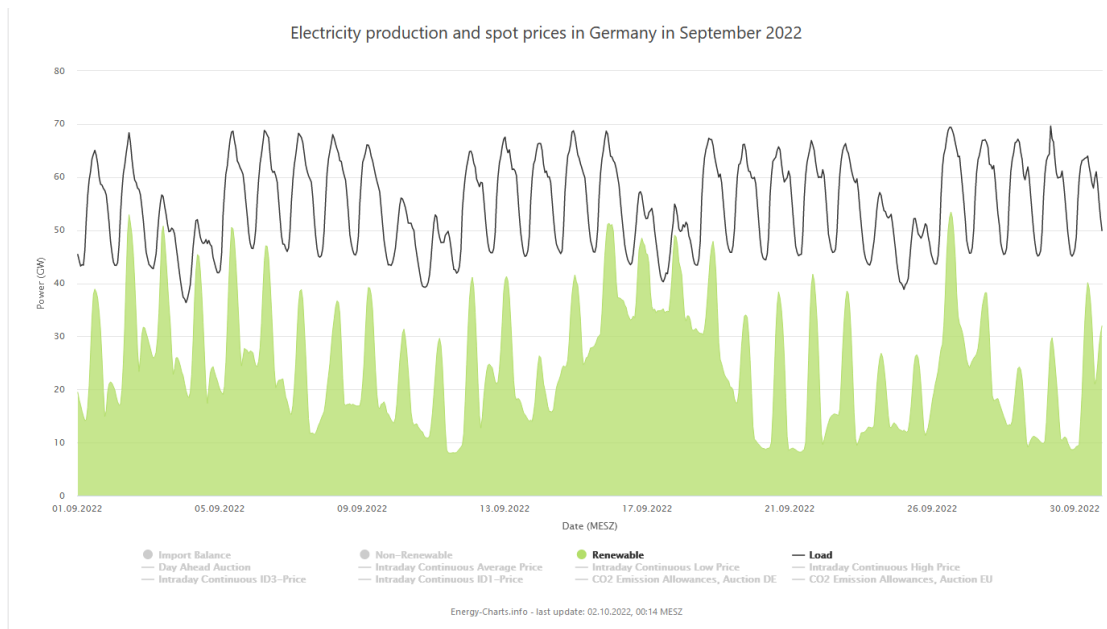


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Outline

- Introduction - Flexibility in the context of biogas systems
- Technical aspects of flexible plant operation
- Economics
- Exemplars of flexible operation
- Conclusion

Demand electricity - different levels

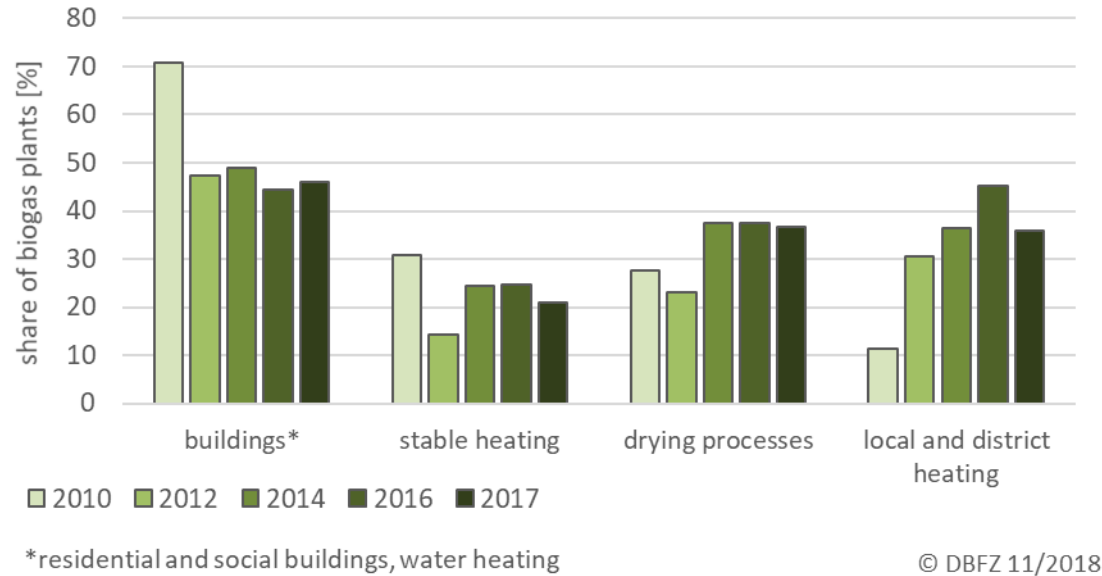


Electricity demand of a dairy farm in Summer (Neiber, 2020)

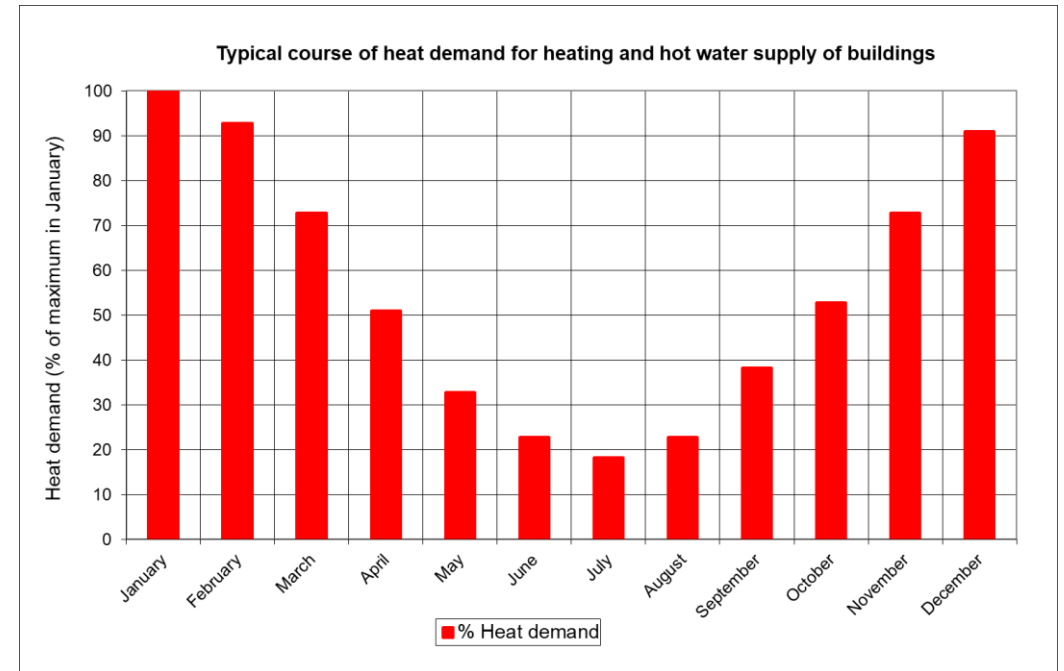
https://energy-charts.info/charts/price_spot_market/chart.htm?l=en&c=DE&interval=month&legendItems=000001000000&month=09

- Depending on the energy customer required flexibility can have complete different requirements
- Grid connection or stand alone?
- Is on site storage (gas, electricity, heat) available?

Demand on the heat site



Development of main heat utilization in Germany for 2010-2017 (Daniel-Gromke et al., 2019a)

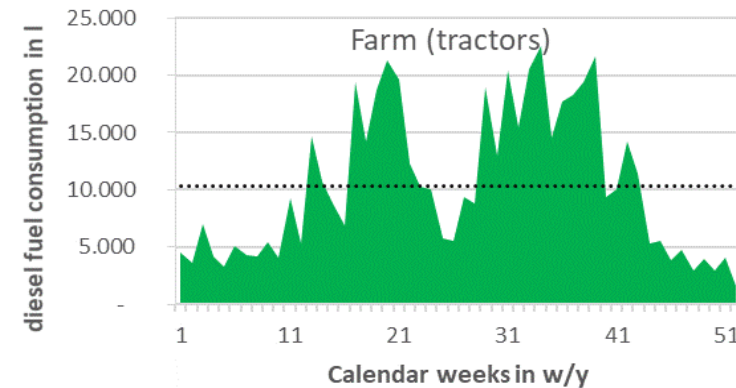
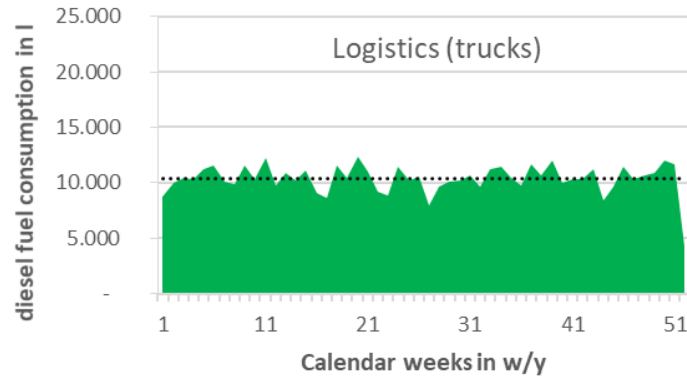


Typical heat demand for heating and hot water supply of buildings with mixed residential and industrial use (Jan Liebetrau, Rytec, own data 2020)

- Heat follows seasonal fluctuations, depending on the type of heat use
- Heat dominated CHP operation is done in Germany occasionally

Demand on fuel supply - fleet supply

Only relevant in case of stand alone fuel station



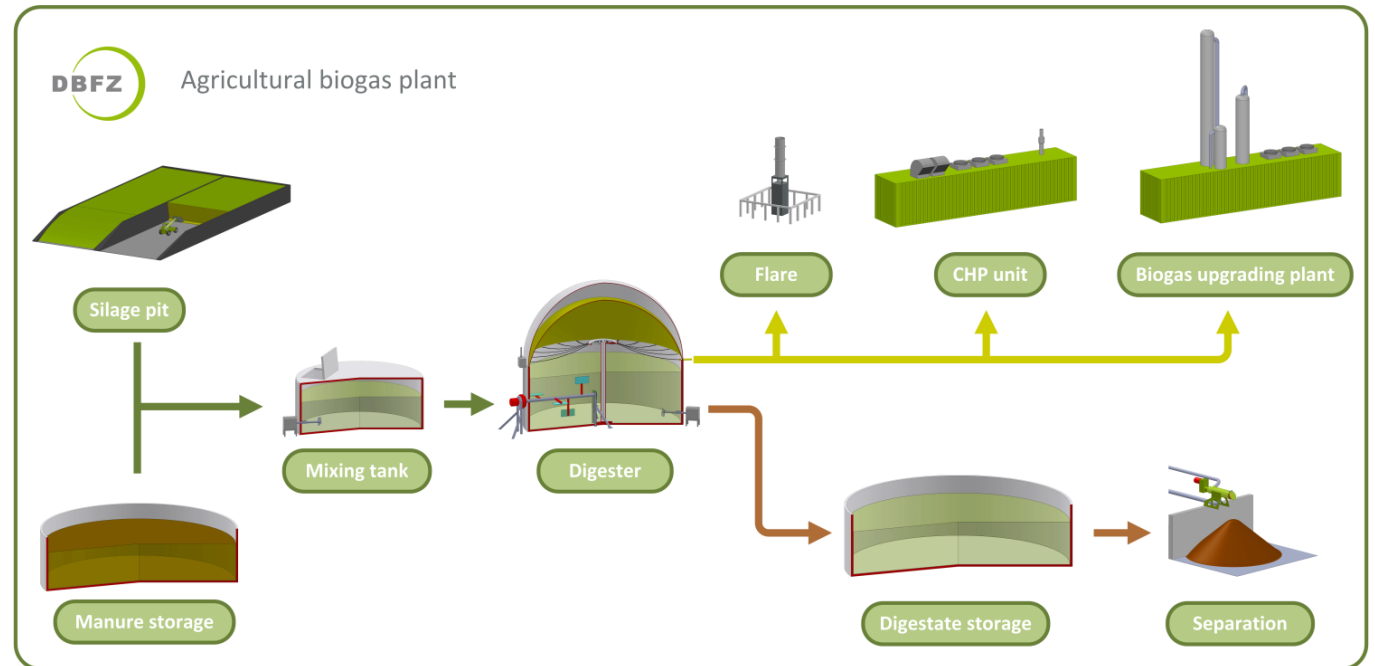
Aggregated fuel demand function for a truck fleet and an agricultural business. (Göğköz et al., 2020)

- Only with fleets somewhat predictable
- Stand alone fuel station has to be developed.

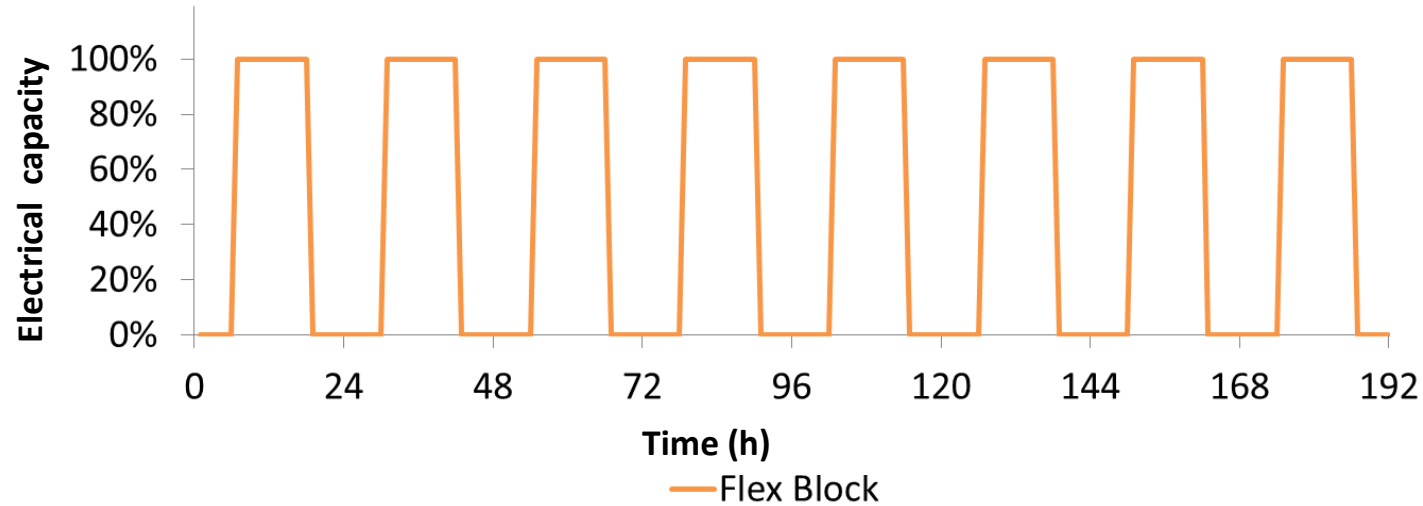
Technical options for flexibility on site

- Flexibility results in reduced capacity utilization or overcapacity is necessary
- This results in higher technical effort and costs, which have to be balanced by the benefits

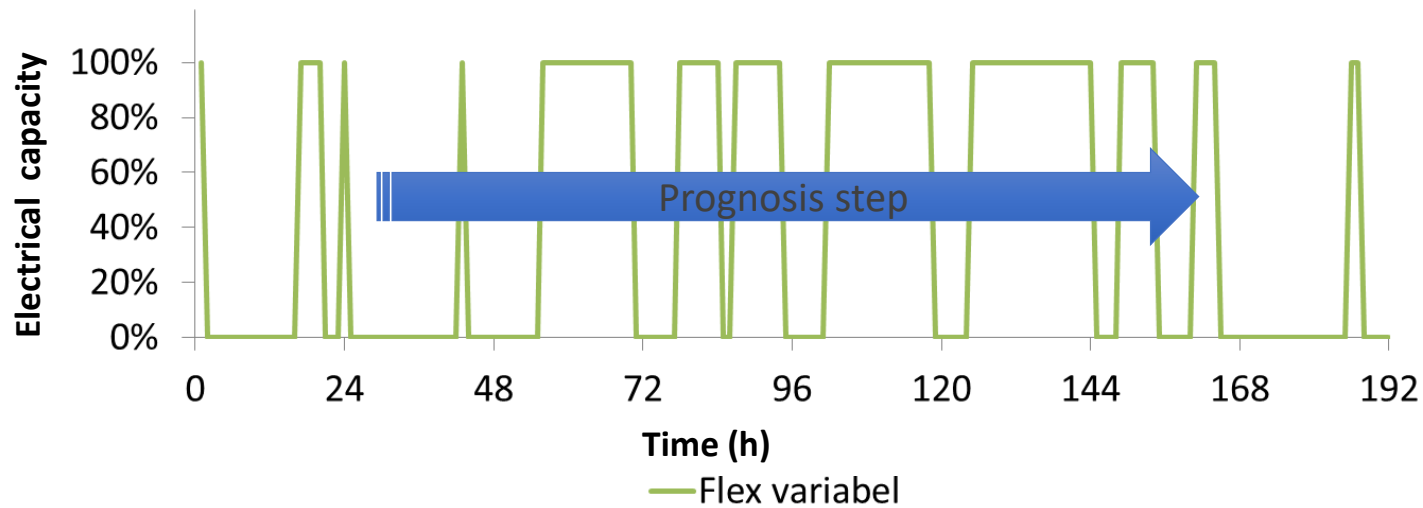
- Increase of CHP capacity (and grid access)
- in case of constant annual energy output
- Increase of gas storage capacity
- Control of biogas production rate
(controlled feeding, storage of intermediates)
- Power to heat
- Biomethane (storage capacity of natural gas grid)
- Power to gas



Quality of flexibility - control aspects



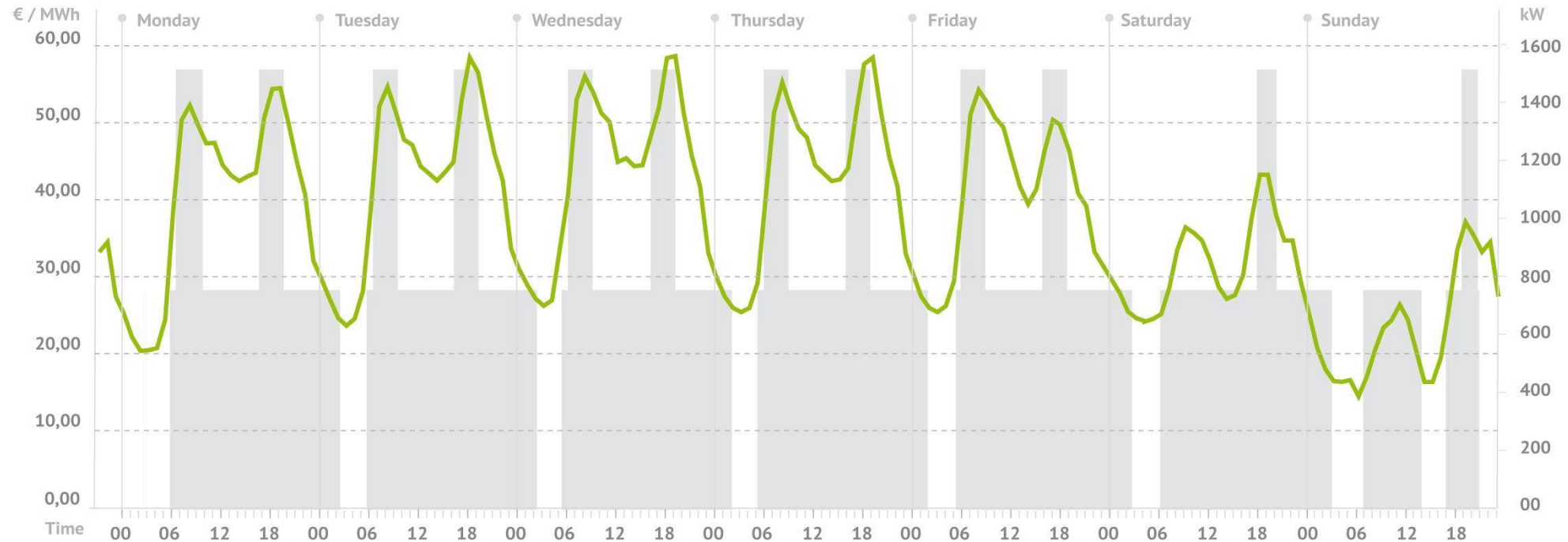
Limited flexibility with standardized fluctuation (e.g. electricity market price oriented)



Flexibility on demand (e.g. ancillary services)

Example of peak load operation

Peak load operation of a biogas unit - example



Price at EPEX Spot Feed-in

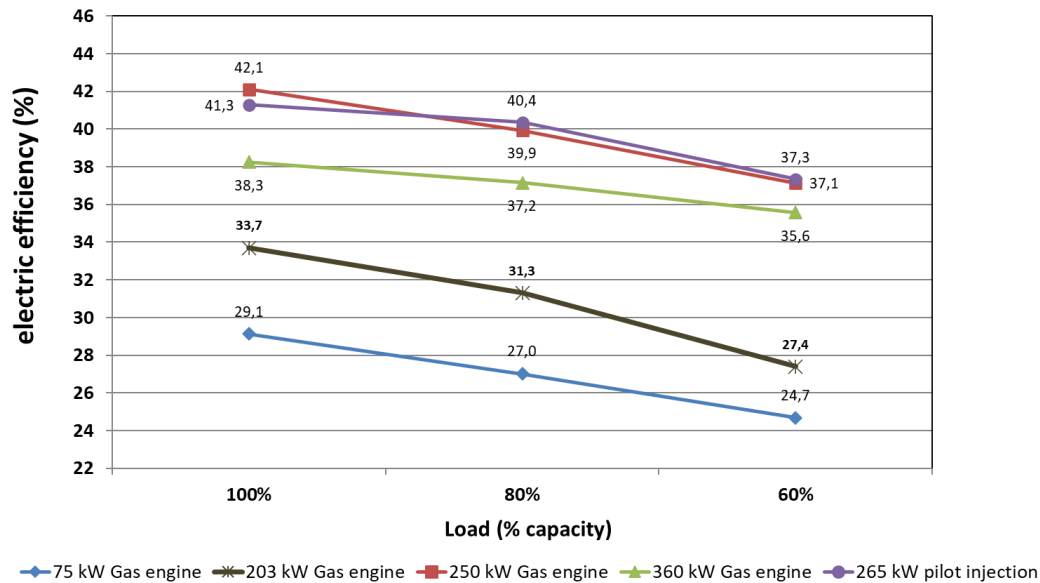
<https://www.next-kraftwerke.com/download-center?category=3&page=4>

CHP operation on flexible plants

- Preheating of cooling water and oil (min. 60 °C);
- Optimized starter and starting procedure of the CHP;
- Recirculation of air in air conditioning;
- Electric oil pressure build up prior to the starting procedure;
- Constructive condensation traps;
- Stainless steel finish at weak points due to sulphuric acid in condensate;
- Remote monitoring and control options for the CHP – PLC;
- Changing requirements for biogas quality (sulphur content, temperature, moisture).

CHP operation on flexible plants

Electric efficiency and part load operation



	100 % Load (203 kW)	90 % Load (183 kW)	80 % Load (162 kW)	70 % Load (142 kW)	60 % Load (122 kW)
Efficiency	33.7 %	31.6 %	31.3 %	29.5 %	27.4 %
CH4 slippage	0.47 %	0.52 %	0.58 %	0.65 %	0.74 %

Part load and methane slippage (Lichti et al., 2018)

Part load operation and efficiency of selected biogas CHPs (Tappen et al. 2017)

Increasing capacity has higher electric efficiency - one large engine is more efficient than two smaller engines combined

Flexible operation - gas management

- Gas storage balances deviation between gas production rate and gas utilization rate
- Gas storage capacity is limited

Potential measures to improve gas management (Reinelt et al. 2019):

- Installation of additional gas storage capacity;
- Sensors for precise filling level evaluation;
- Installation of a gas management (transportation) system between the gas domes via a controllable blower for inflation air;
- Dimensions of gas transportation lines;
- Dimensions of gas treatment devices (e.g. gas dryers).

Plus:

- Feeding management can alter gas production rate to provide gas when needed
- Model based control gives information on gas production rate of substrate mixes

Control of biogas production rate

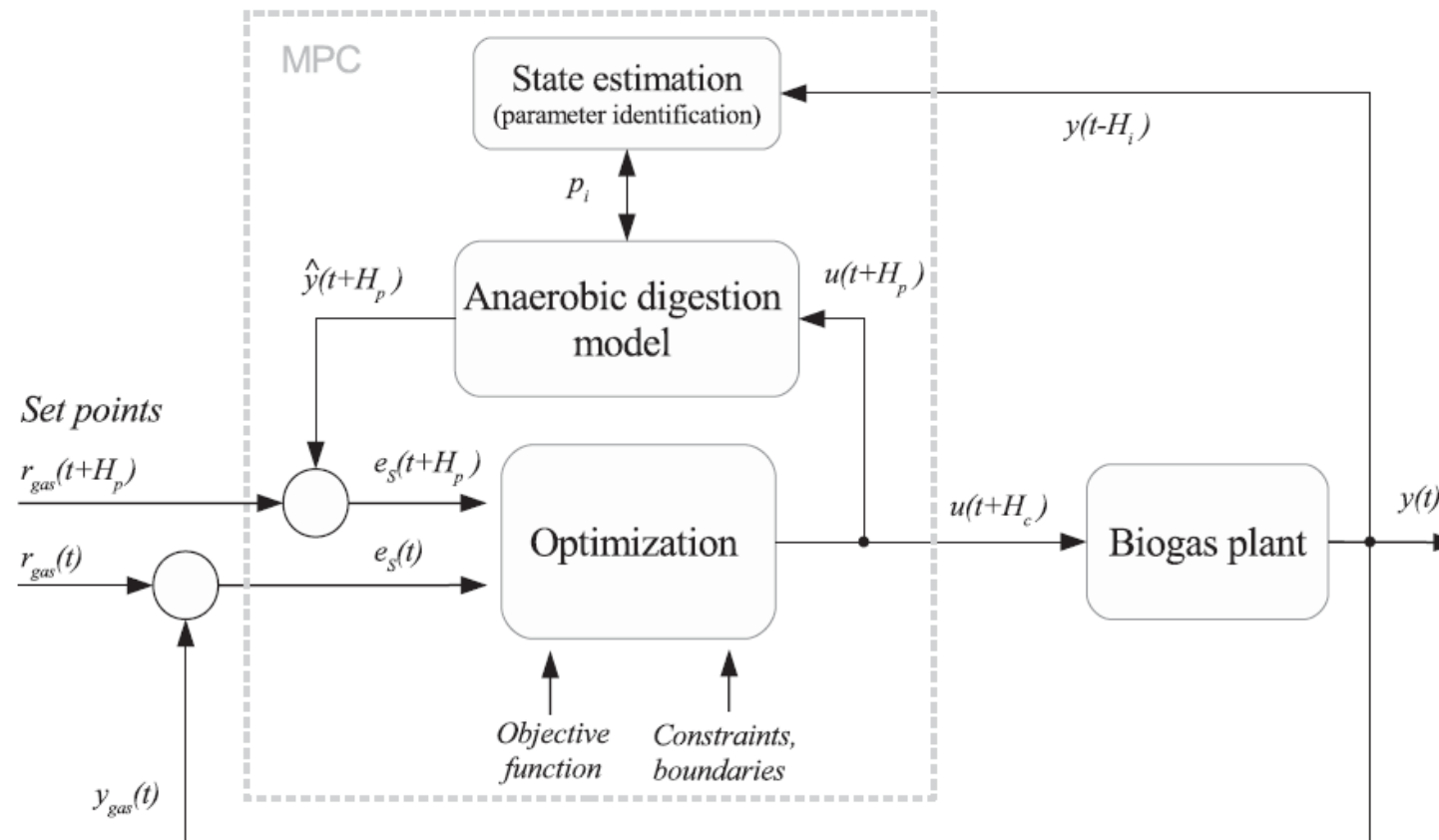
Block diagram of the applied model predictive control (MPC) algorithm

set variable:

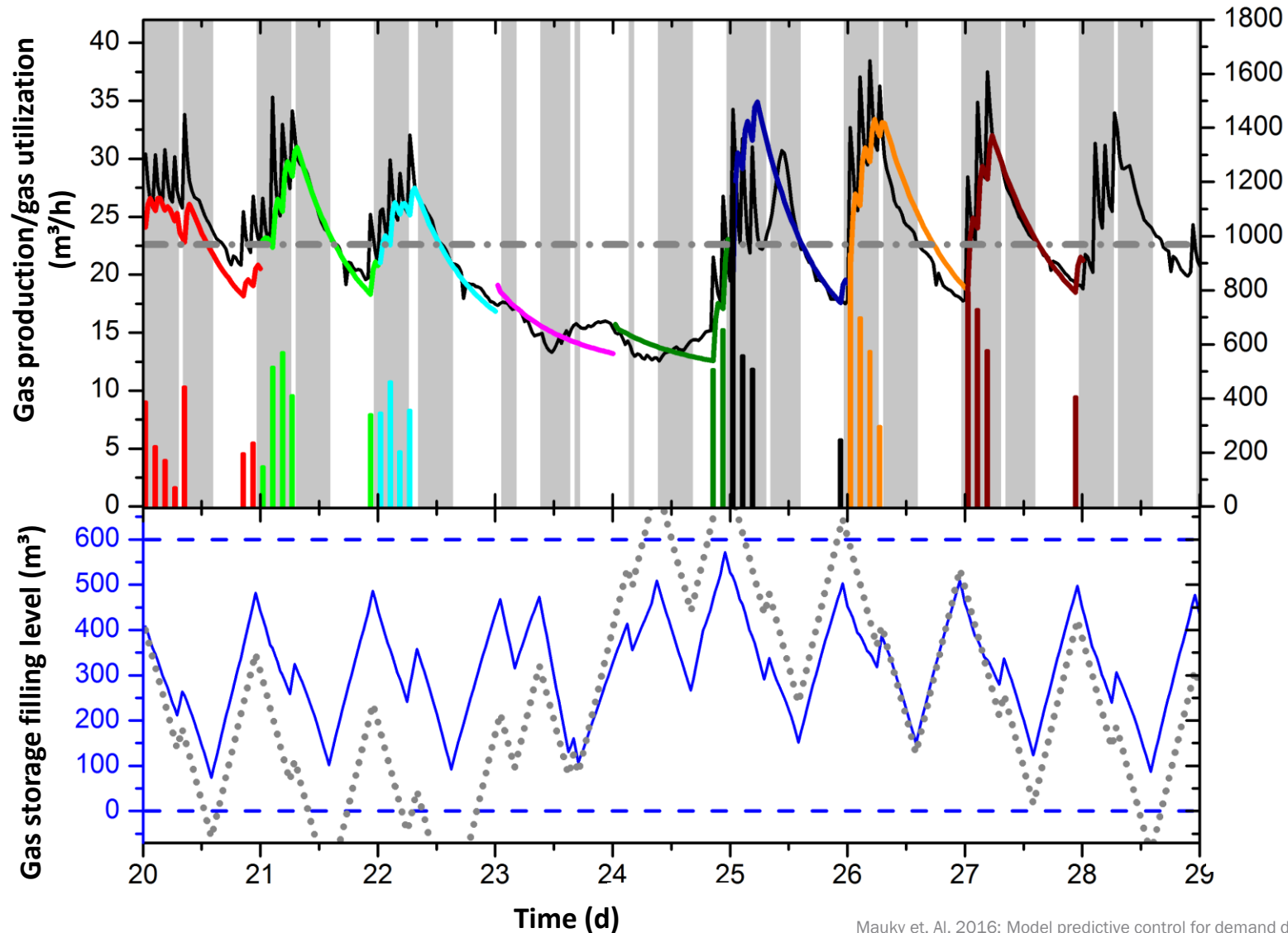
substrate type
feeding amount

control variable:

gas storage filling level



Controlled biogas production



45%
Less gas storage
capacity

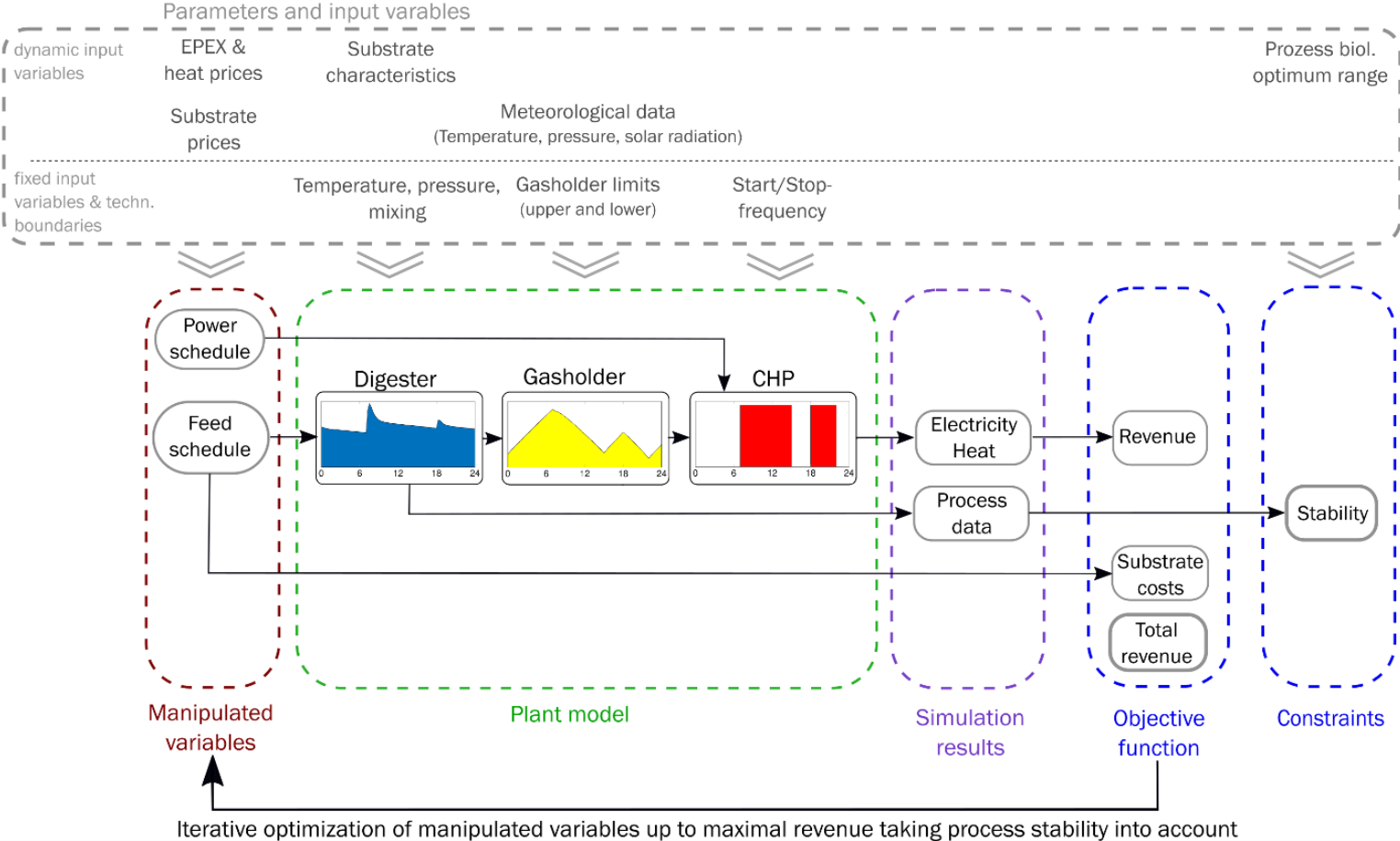
Forward-looking process management according to a given schedule of energy demand

Component design needs to be adjusted to variable energy provision, flexibilisation can have an impact on all components of processing

Process optimization including external factors

Flexibilisation requires the integration of external factors and internal limitations

Increasingly complex optimisation tasks and complex monitoring and control tasks



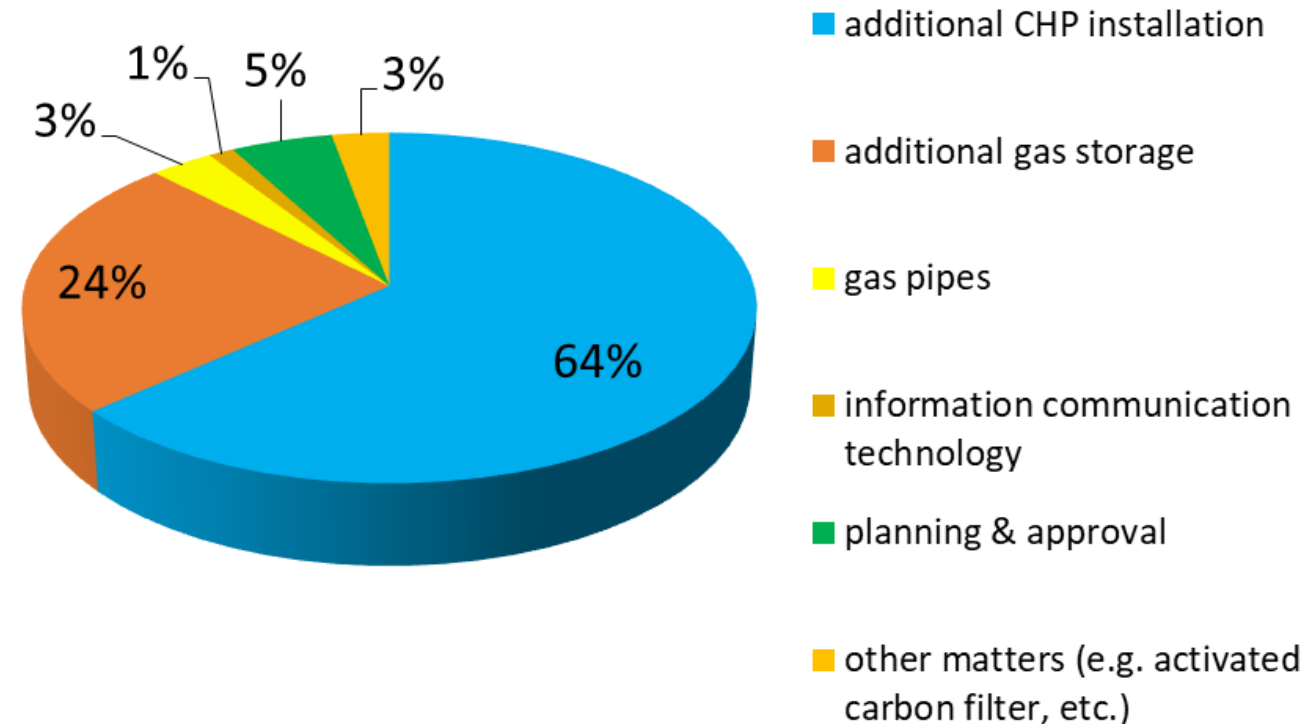
Source: DBFZ 2019

Example for a more comprehensive process control considering technical and economic requirement (data from DBFZ) (EPEX: European power exchange – market for electricity)

Economics of flexible operation

General economics - aspects to be considered

- Capex and opex for a given degree of flexible operation
 - Additional capacity installation
 - Additional maintenance effort
 - Costs related to decreasing capacity utilization
- Revenues and contracting conditions for the energy products
- Long term prognosis of the energy markets



Source: Barchmann, DBFZ

Economics of flexible operation

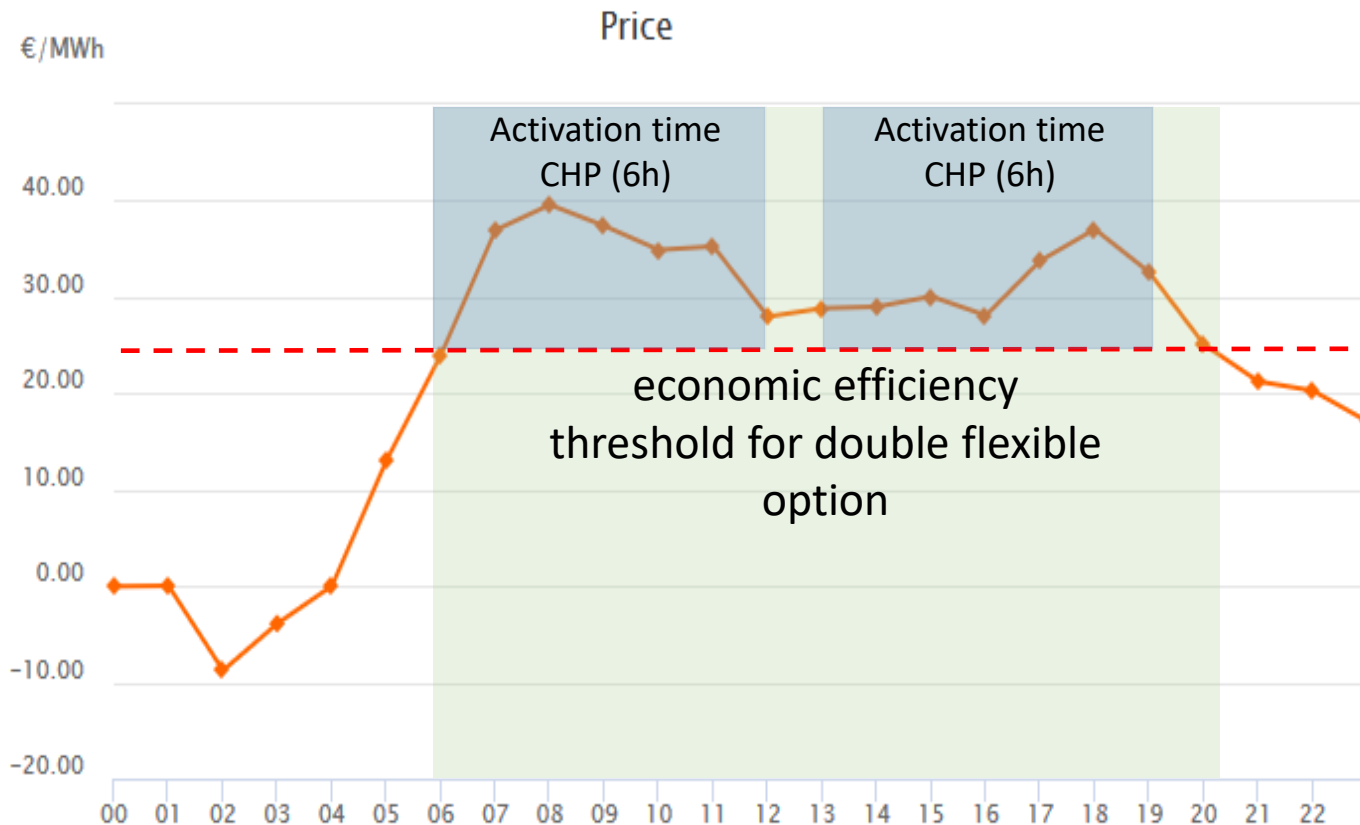
General economics - difference between base load plants and flexible plants concerning production cost

Flexibilisation factor	Reference	Flexibilisation options			
	none Base load operation	2 Flexibilisation Downsizing	2 Flexibilisation Upsizing	4 Flexibilisation Upsizing	
Installed power	500	500	1.000	2.000	
Nummer CHP units	1	1	2	4	
Operation time h/a	8.000	4.000	4.000	2000	
Power sold kWh/a	3.960.000	1.980.000	3.960.000	3.960.000	
Component	Investment [€]	Investment [€]	Investment [€]	Investment [€]	
CHP	453.902	453.902	907.804	1.815.608	
Flare	123.288	77.163	123.288	123.288	
Pumpstation	64.844	41.173	64.844	64.844	
Solid feeding unit	336.956	186.622	336.956	336.956	
Digester	505.077	297.236	505.077	505.077	
Digestate Storage	379.326	228.615	379.326	379.326	
Gasstorage	95.320	95.320	170.213	680.853	
Sum of investment	1.958.713	1.380.031	2.487.508	3.905.952	
Planing and construction preparation	195.871	195.871	195.871	195.871	
Complete investment for biogas plant	2.154.585	1.575.902	2.683.379	4.101.823	
Annual cost (20 years operating time)					
Capex	[€/a]	294.618	223.029	394.032	687.831
Opex feedstock and resources	[€/a]	403.479	201.740	403.479	403.479
Opex misc	[€/a]	42.395	42.395	42.395	42.395
Sum	[€/a]	740.492	467.163	839.906	1.133.705
Specific cost					
Power production cost	[€/kWh]	0,187	0,236	0,212	0,286
Difference to reference	[€/kWh]	x	0,049	0,025	0,099

- Cost-based approach with new constructed biogas plants
- no national specific assumptions regarding funding systems
- 500 kW agriculture biogas plant as example
- Feedstock: 30 % manure, 40 % maize, 30 % sorghum
- **One more CHP-unit at the same annual power production level, means approx. 3 €/kWh higher production cost**

Economics of flexible operation

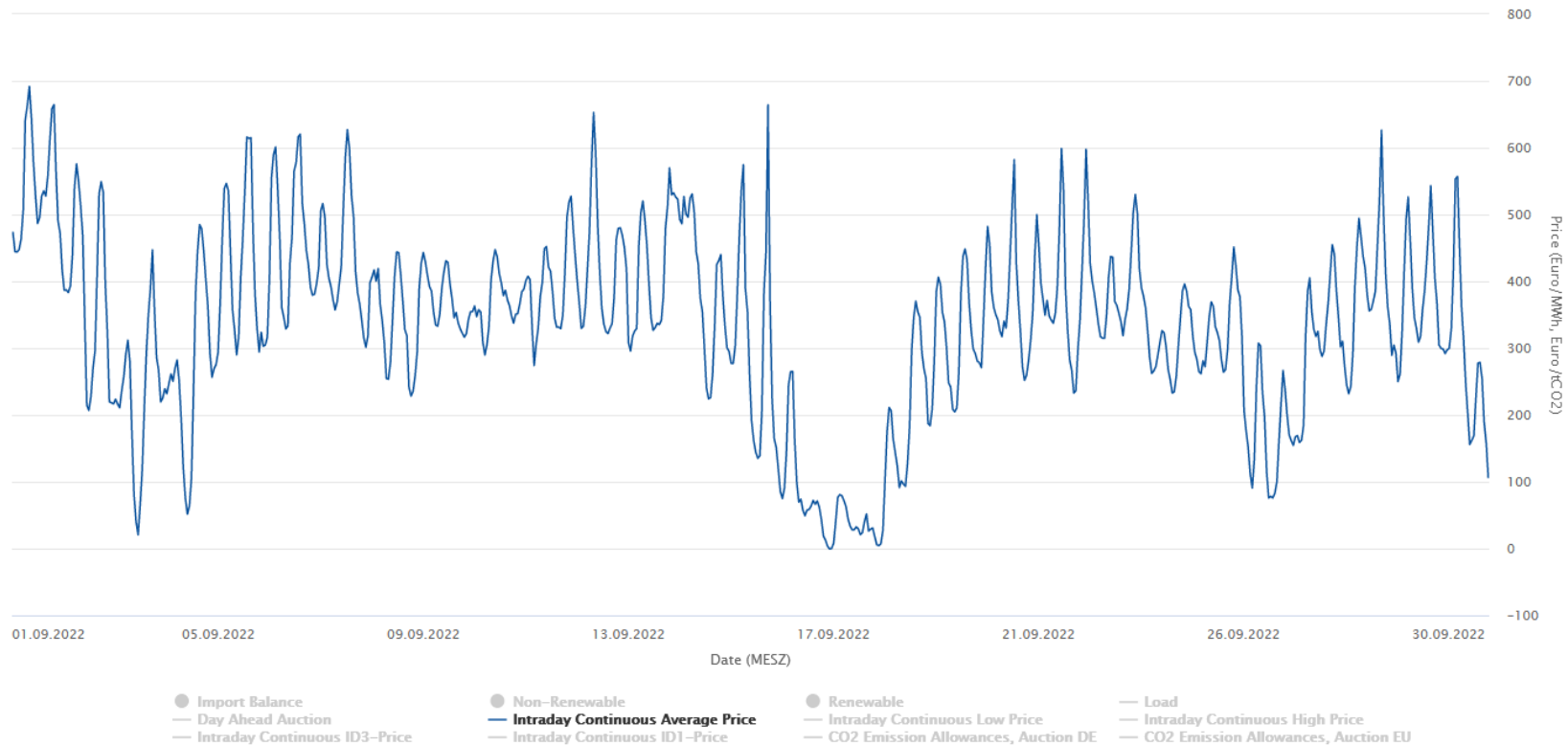
General economics - revenues of flexibilisation (market)



- higher expenses must be compensated by interacting with the volatility of the market
- Market potential is very limited for the payment of flexibility
- Expected additional revenues approx. 0.5 till 1.5 €cent/kWh in average
- Maximum values can be much higher
- Possibility for additional revenues depends on price spread

Economics of flexible operation

Electricity production and spot prices in Germany in September 2022



Energy-Charts.info - last update: 02.10.2022, 00:14 MESZ

Exemplars of flexible operation

Bioenergie Langwedel GmbH & Co. KG



- Commissioned in 2010;
- Substrates include for over 50% liquid cattle slurry and dung, less than 30% corn silage with the remainder of feedstock comprised of cereal crop silage and cereals;
- Flexible operation since February 2019;
- The average output is 486 kW; installed capacity of 2,356 kW;
- The maximum gas storage capacity (at average gas production) is 16 hours;
- The volume of gas storage is 5.000 m³
- Heat storage of 1,000 m³ of hot water

Marketing concept:

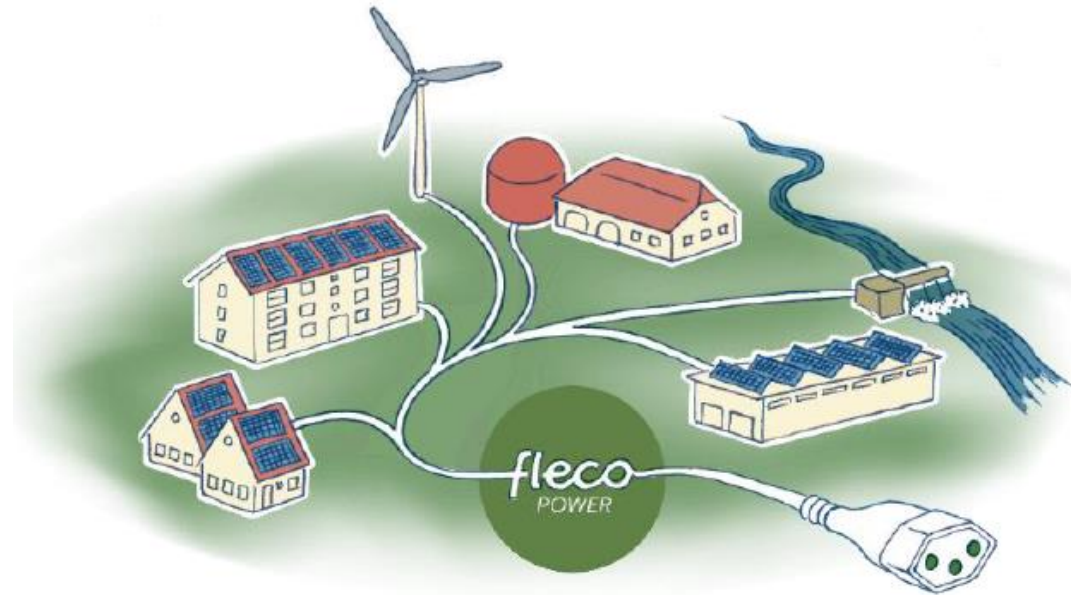
- Individual electricity market oriented operation for the following day (day ahead market) and participation in “intraday” market;
- CHP units have approximately 1,800 h/a full load operation;
- Remote control from electricity trader; which can directly access the process and process relevant parameter;
- Additional income expected in 2019 of more than 1.5 ct€/kWh;
- Operate with a maximum of 2 starts per day with a minimum of 1 hour of operation with both CHP units in full load, shift of electricity production to winter;
- The heat from the CHP unit is used to heat buildings and barns and dry digestate;
- 95 % of available heat is used.

Exemplars of flexible operation

Flexibilisation in Switzerland - Virtual Power Plant

The Swiss virtual power plant “Fleco Power” represents a marketplace to match flexibility of producers and users of new renewable energy.

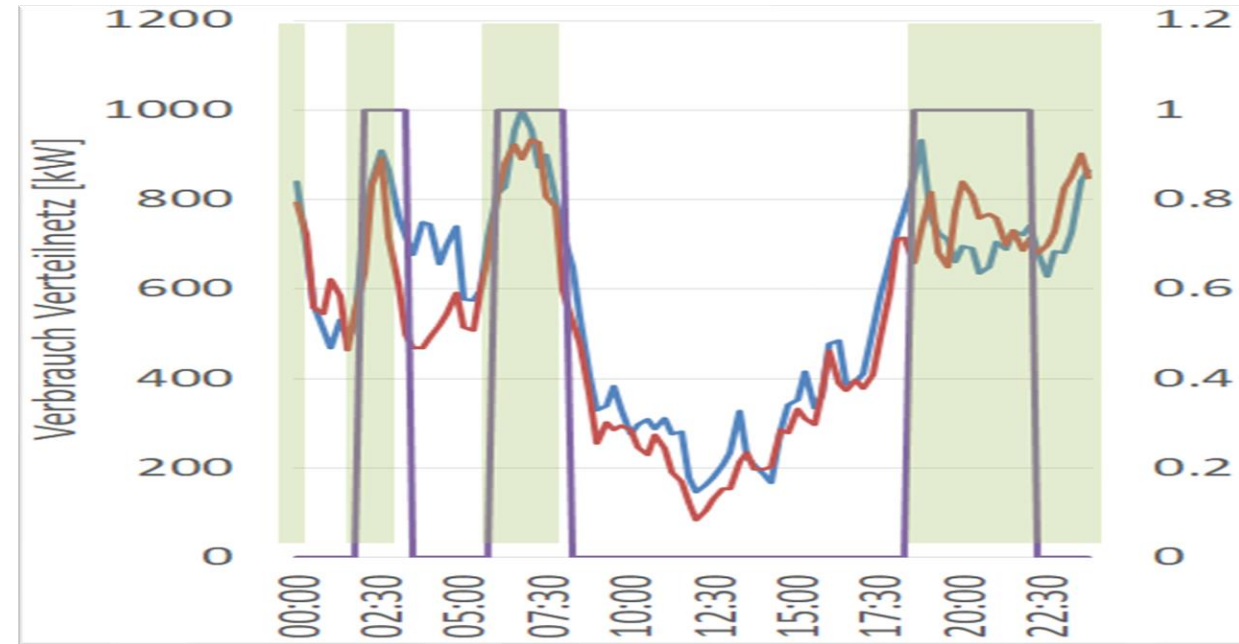
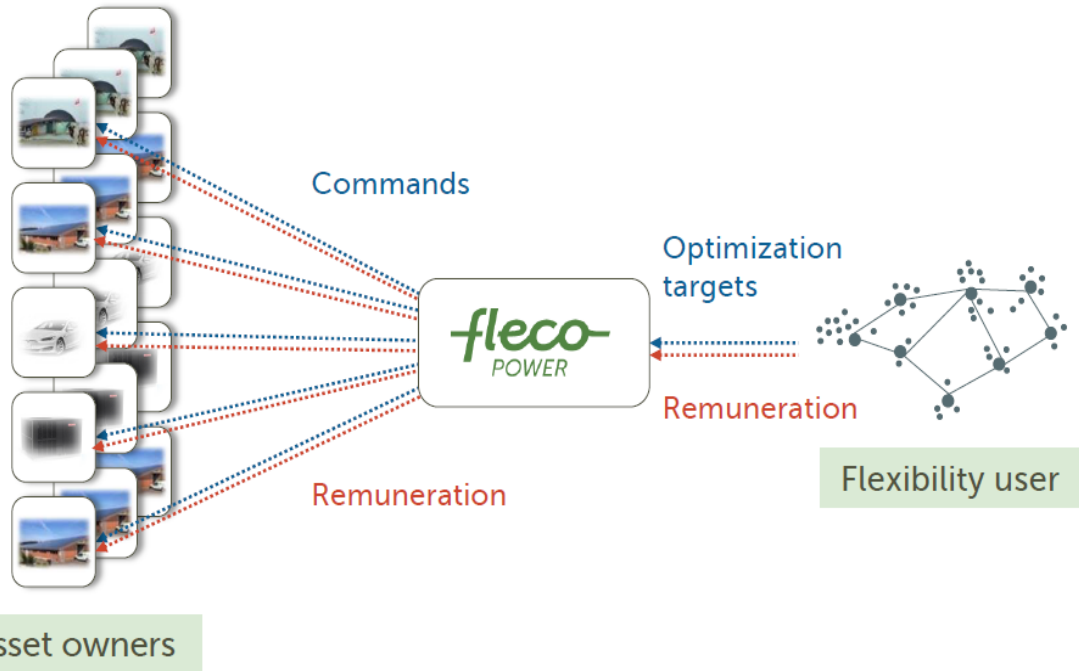
The flexibility of over 80 biomass, small hydroelectric and photovoltaic plants with a nominal power of 30 MW is bundled and marketed as control energy to Swissgrid, the Swiss electricity grid operator.



Fleco Power Structure to combine flexibility of decentralized installations

Exemplars of flexible operation

Flexibilisation in Switzerland - Virtual Power Plant



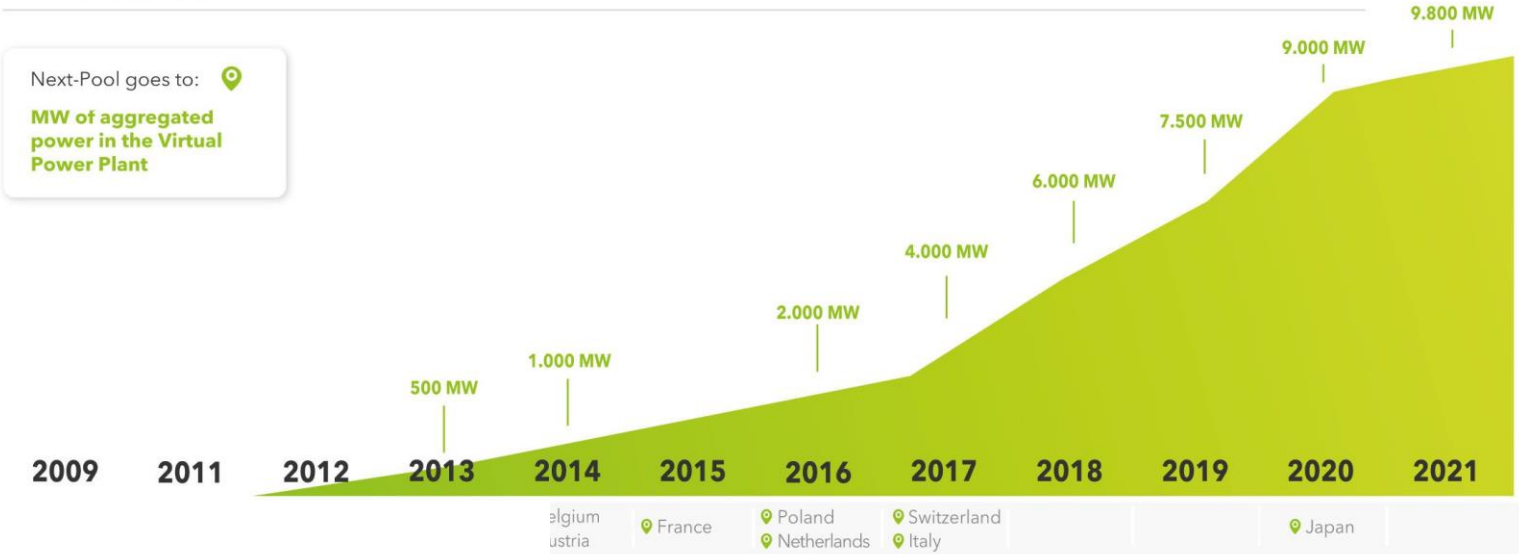
Example of a 1-day flexibility control time course of a biogas installation in Switzerland in Autumn.

green: peak load time windows. blue/red: Historical load curves of electricity demand.

violet: biogas CHP timetable

Virtual power plants - Exemplar in Germany

Milestones



Facts & Figures

Aggregated Units

14 841 Q3/2022

Networked Capacity

11 182 MW Q3 2022

Annual Sales

595 € million (2020)

Volume of traded energy

15.1 TWh in 2019

Employees

254

Foundation

2009 Next Pool

Conclusion

The **perception of the role of biogas has changed** from traditionally seen as a means of treatment of a range of wet organic wastes towards a **source of renewable energy as part of a new energy system**.

In the near future the integration of energy vectors will be essential in facilitating PV during daylight hours, wind power on windy days and renewable sources of dispatchable energy such as from bioenergy.

The **biogas plant operation** itself can be controlled extensively and with this control **comes high levels of flexibility**.

Biogas systems can be a node of integration between electrical and natural gas grids in providing a sink for electricity (through power to gas systems) that would otherwise be curtailed or constrained.

The flexibility of biogas systems can facilitate energy delivery to:

- the electricity grid as close as possible to the electricity demand profile
- heat to consumers facilitating the seasonal demand profile of heat;
- to the gas grid to decarbonize gaseous fuels for various purposes;
- Biomethane directly to local consumers such as for transport biofuel for haulage and buses;
- Biogas can play an essential role as part of a virtual power plants.

A Technical report from IEA Bioenergy Task 37

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Find the report on the Task 37 web site under:

https://task37.ieabioenergy.com/files/daten-redaktion/download/Technical%20Brochures/Flex%20report_END_WEB.pdf



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IEA Bioenergy: Task 37

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Thank you for your interest

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