IEA Bioenergy
Technology Collaboration Programme

Integration of biogas systems into the energy system

Technical aspects of flexible plant operation

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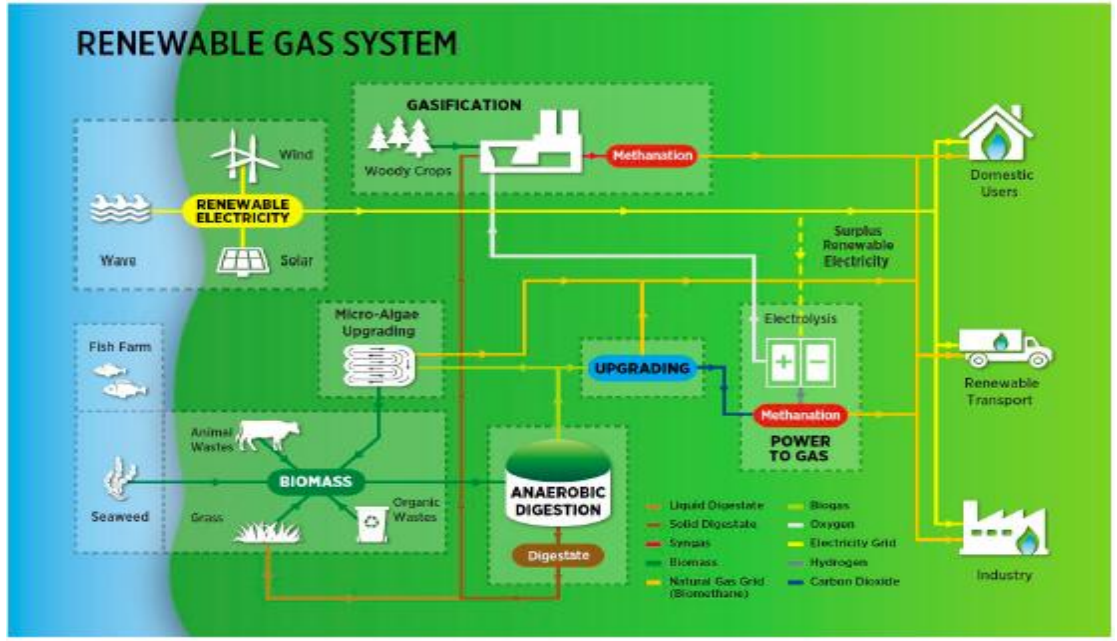
Webinar:
Flexibility Provision from Biogenic Gases
23th of November 2022

IEA Bioenergy Task 37 - Energy from Biogas

- Assessment of co-benefits of biogas in a circular economy system
- Detailed assessment of an optimised utilization of manure
- Decarbonisation of food and beverage industry
- Energy and transport fuels from renewable gases
- Efficacy of continuous tests
- How to reduce the methane slip at biogas systems and landfill
- Economics and GHG marginal abatement costs



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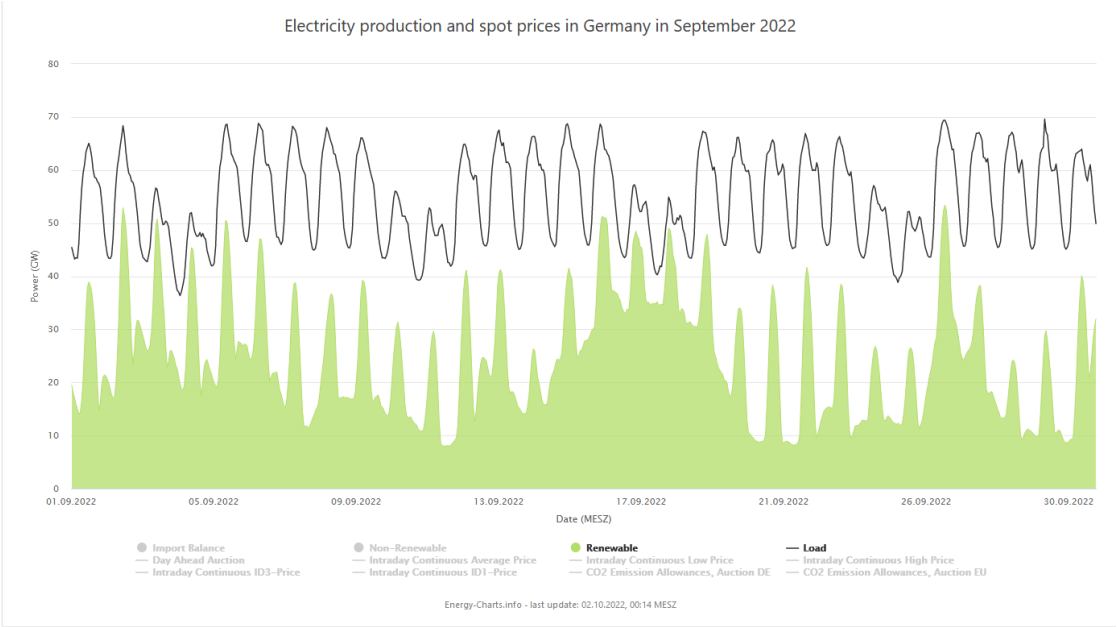
Outline

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

Demand electricity - different levels



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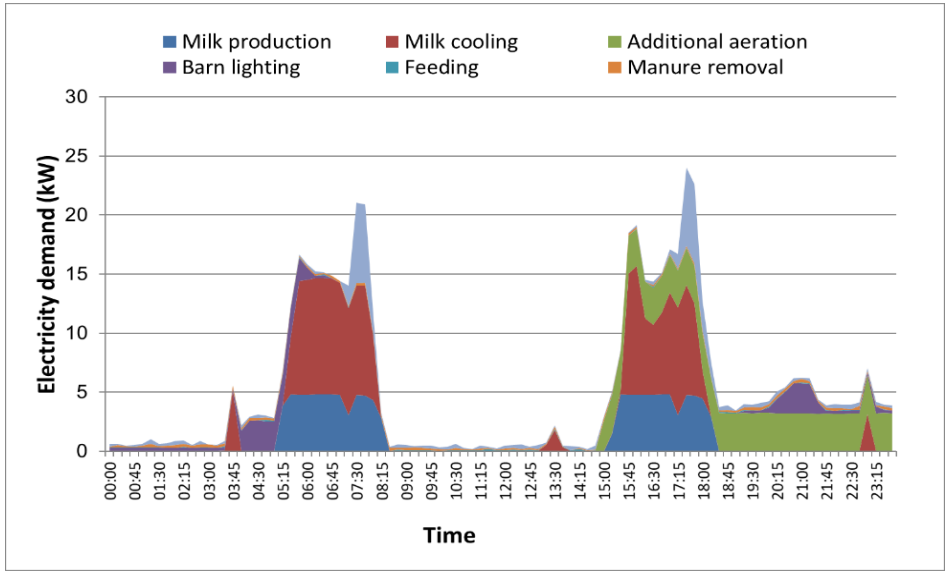
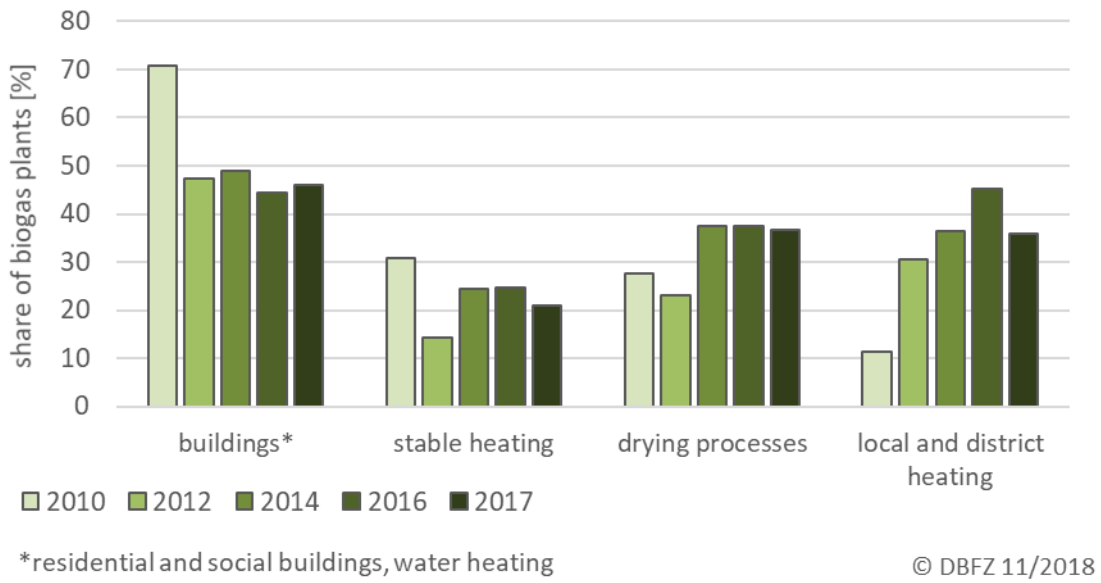


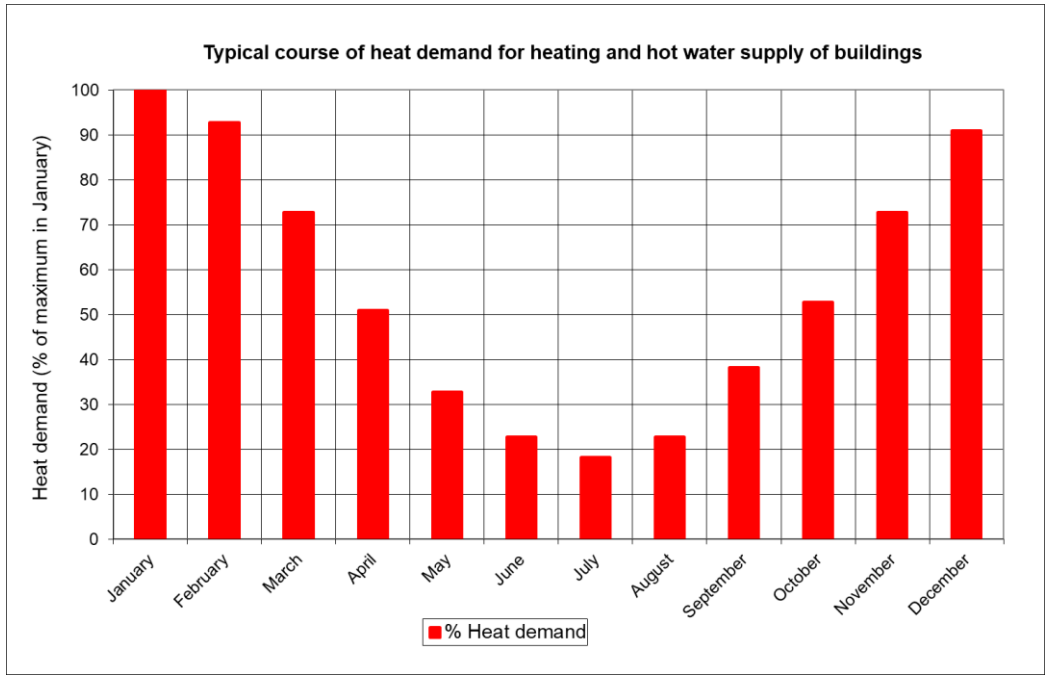
Electricity demand of a dairy farm in Summer (Neiber, 2020)

- Depending on the energy customer required flexibility can have complete different characteristics
- Grid connection or stand alone? Which energy forms under contract have which demand?
- Is on site balancing capacity as 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)

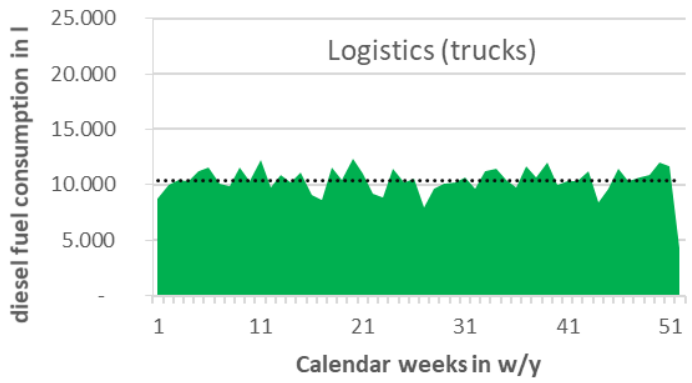


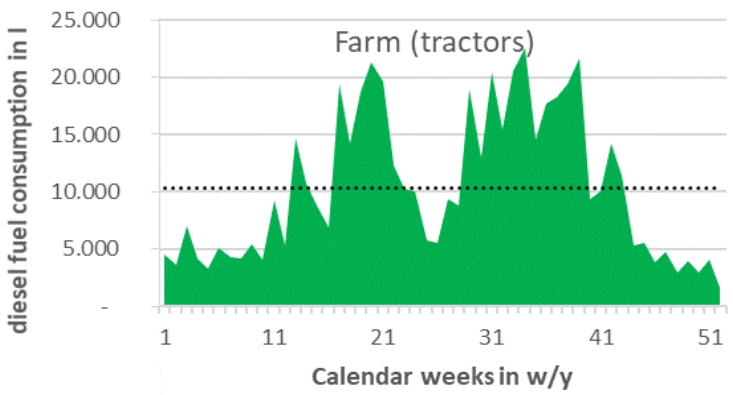
Typical heat demand for heating and hot water supply of buildings with mixed residential and industrial use (Jan Liebetrau, Rytec, own data 2020)

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

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. (Gögköz et al., 2020)

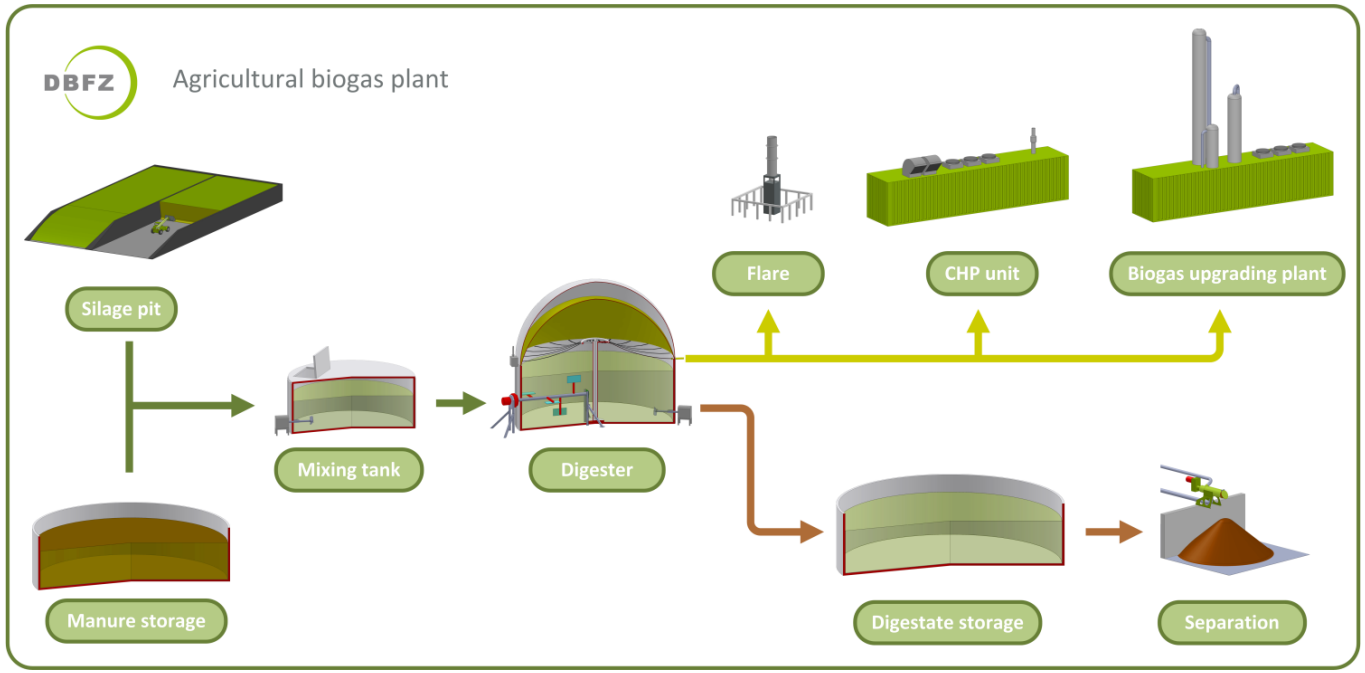
- Only with fleets somewhat predictable
- Stand alone fuel station has to be developed.

Technical options for flexibility on site

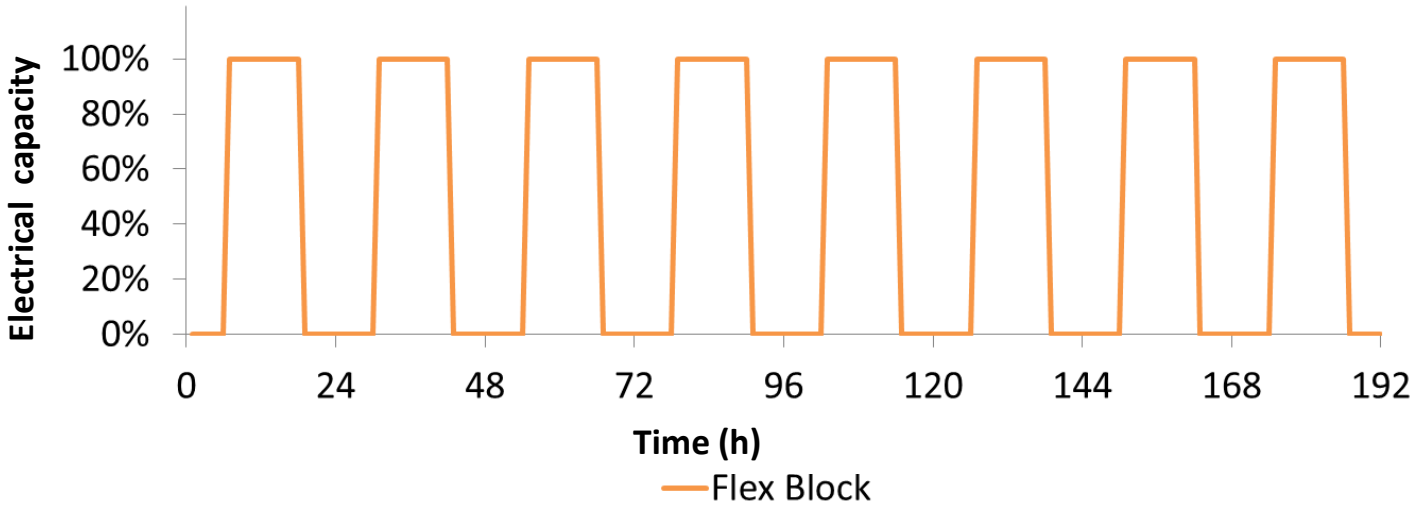
- Flexibility results in reduced capacity utilization or overcapacity is necessary
- This results in higher technical effort and costs, which have to be balanced by the benefits

- 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)

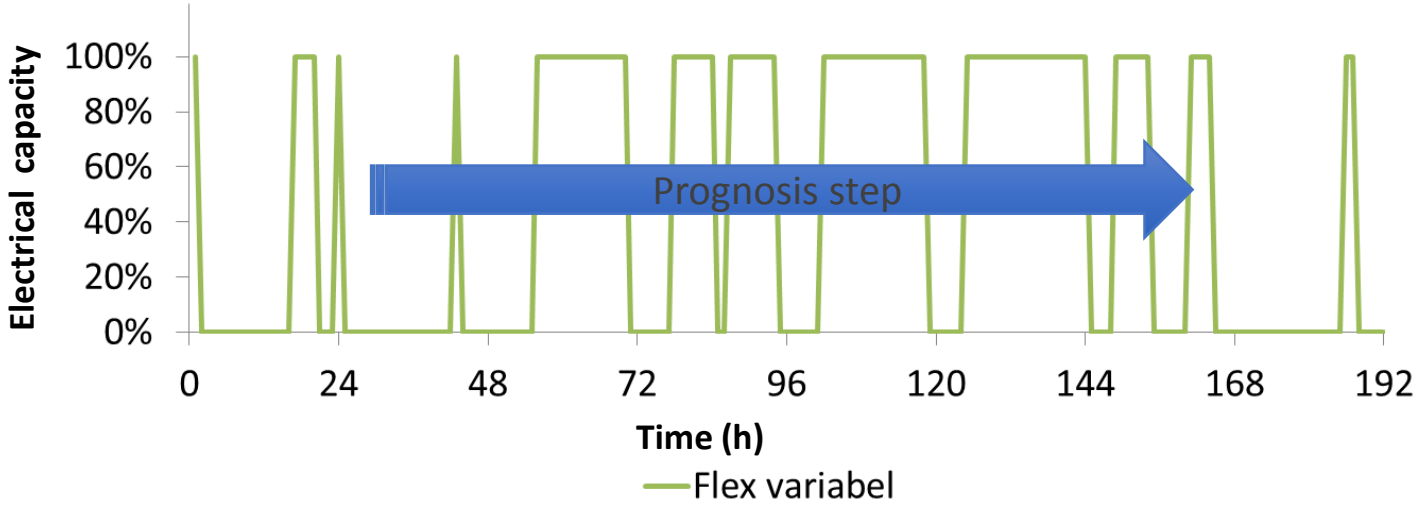
- Power to heat
- Biomethane (storage capacity of natural gas grid)
- Power to gas



Quality of flexibility – control aspects

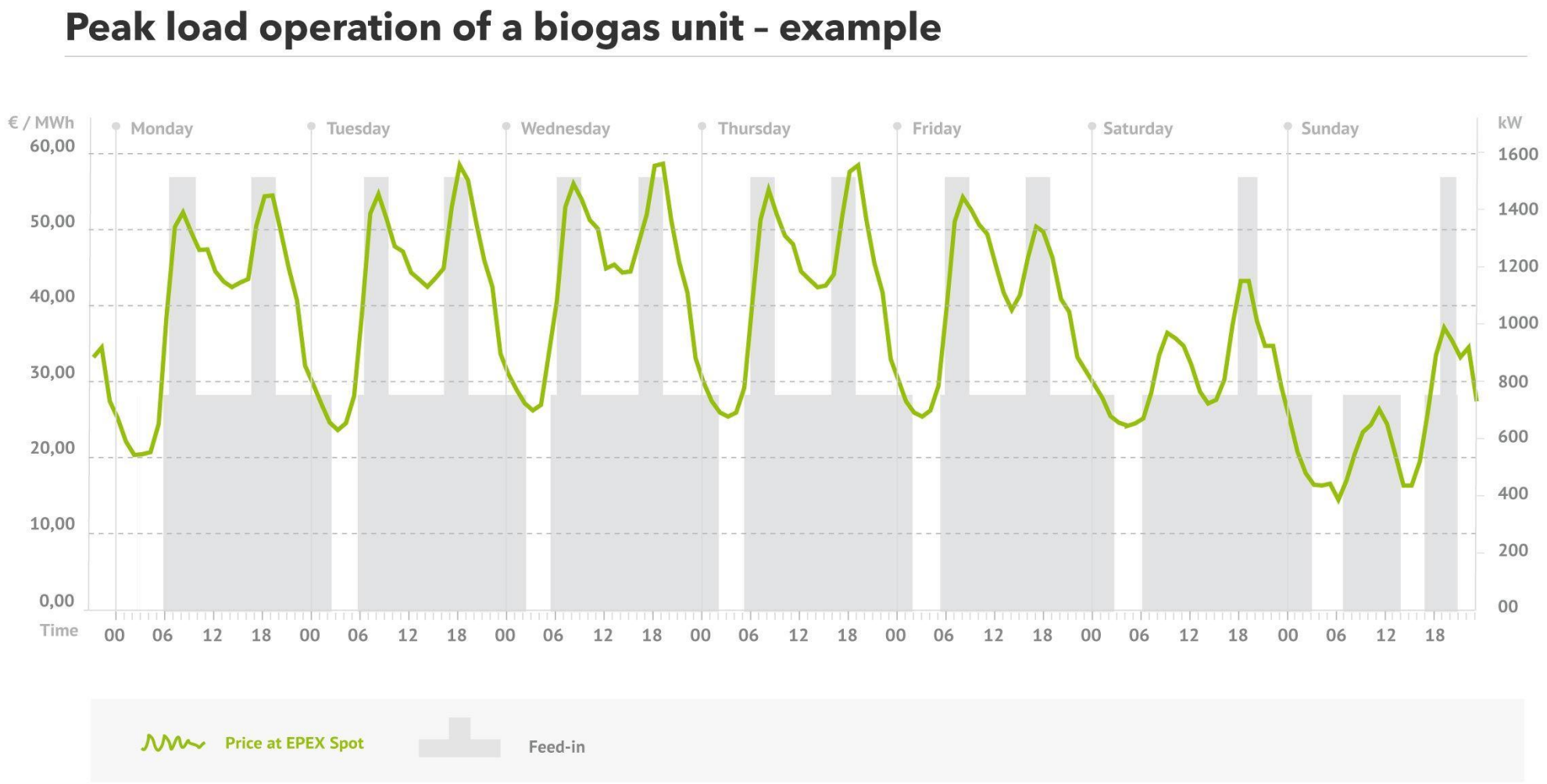


Limited flexibility with standardized fluctuation (e.g. electricity market price oriented)



Flexibility on demand (e.g. ancillary services)

Example of peak load operation

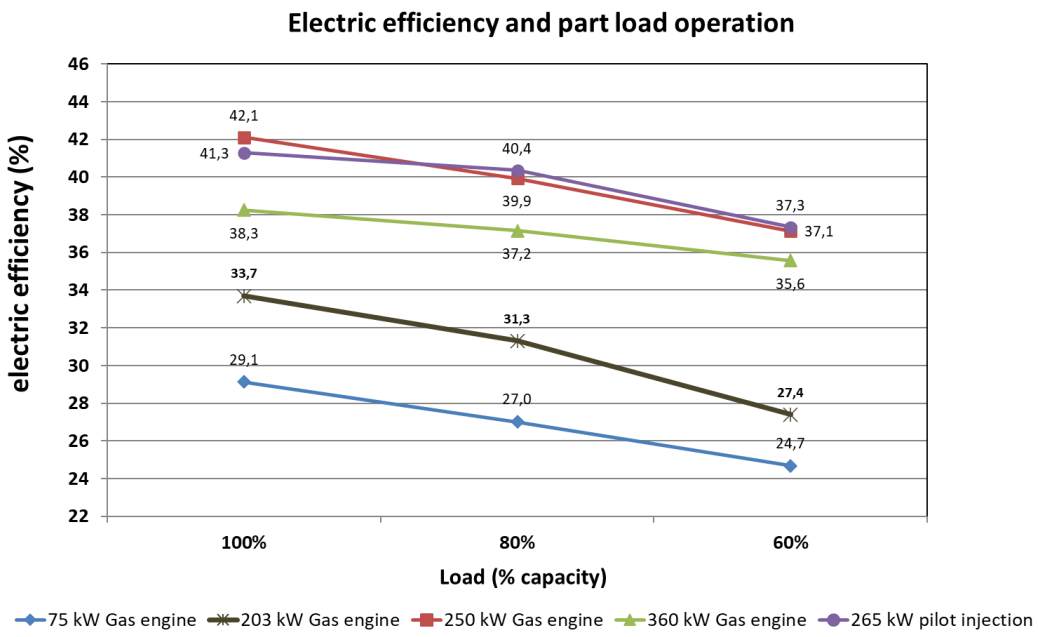


Source: https://www.next-kraftwerke.com/download-center?category=3&page=4

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



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

	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)

- Increasing capacity of CHP capacity has higher electric efficiency - one large engine is more efficient than two smaller engines combined
- On/off better than part load

Flexible operation – gas management

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

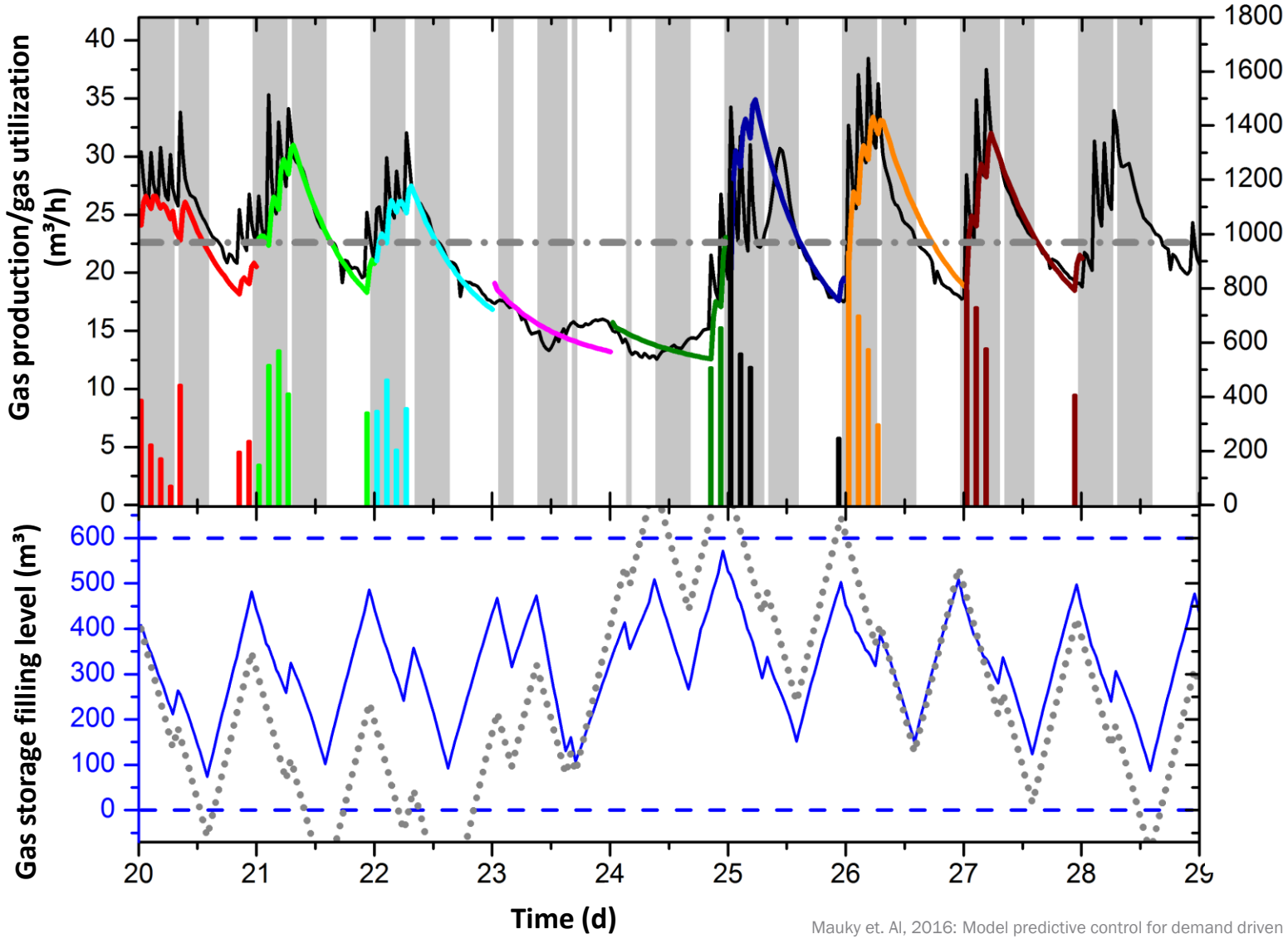
Potential measures to improve gas management (Reinelt et al. 2019):

- 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

Controlled biogas production



45%
Less gas storage capacity

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

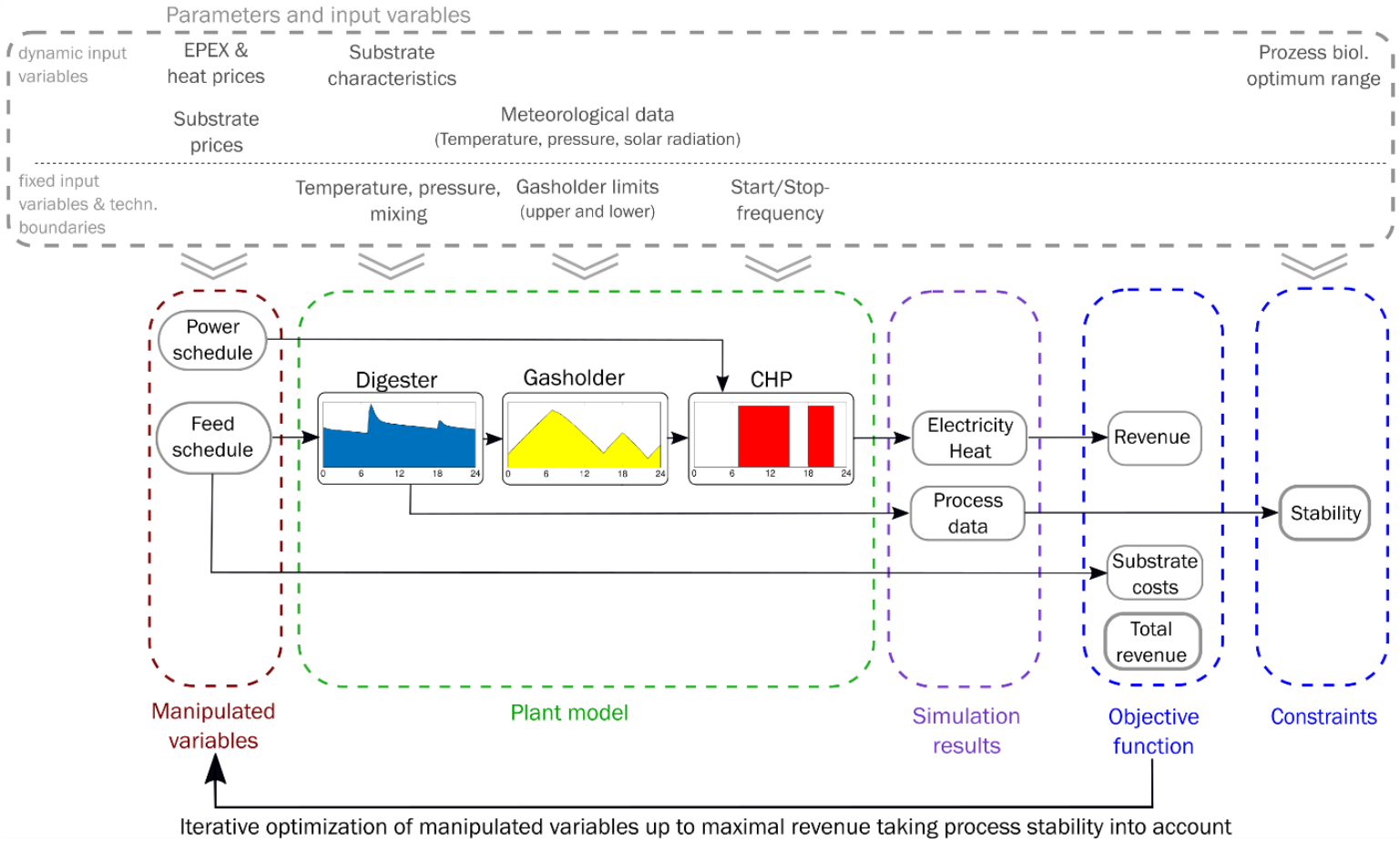
Component design needs to be adjusted to variable energy provision, flexibilisation can have an impact on all components of processing

Mauky et. Al, 2016: Model predictive control for demand driven biogas production in full scale, Chem. Eng, Technol. 2016, 39, No 4

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



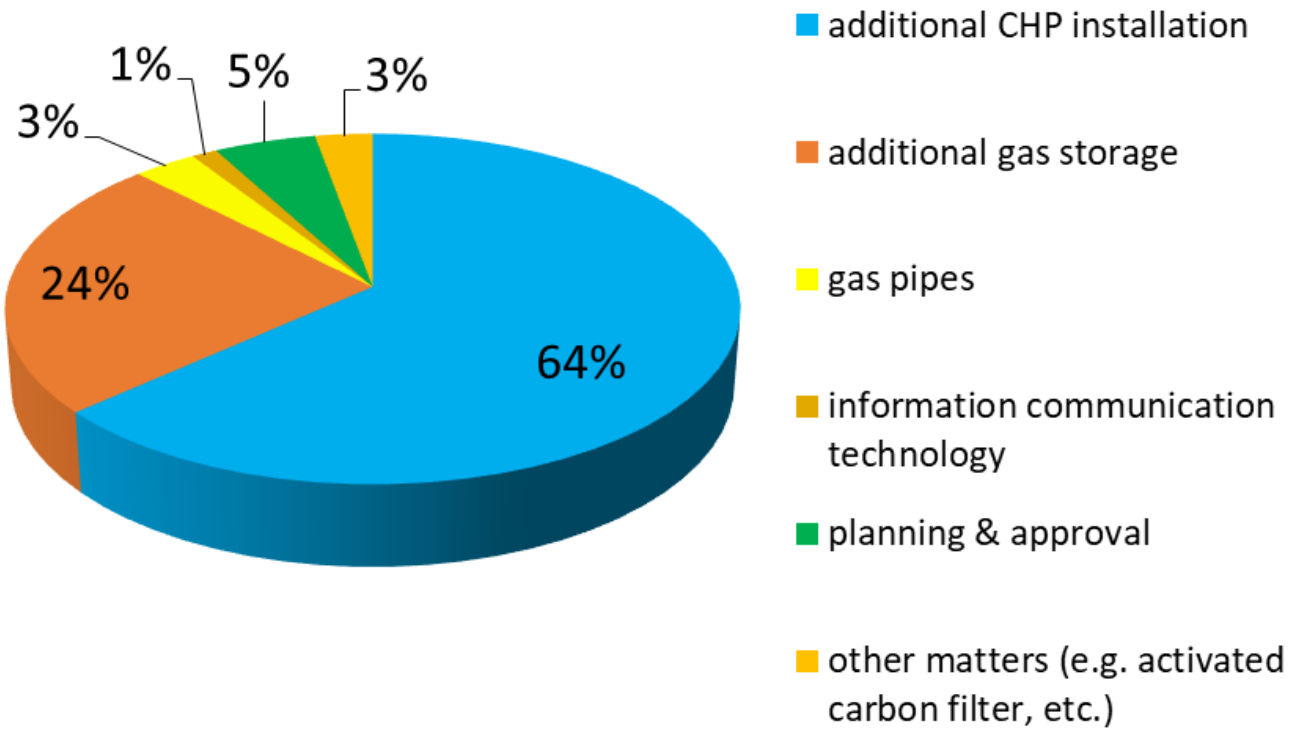
Source: DBFZ 2019

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 considererd

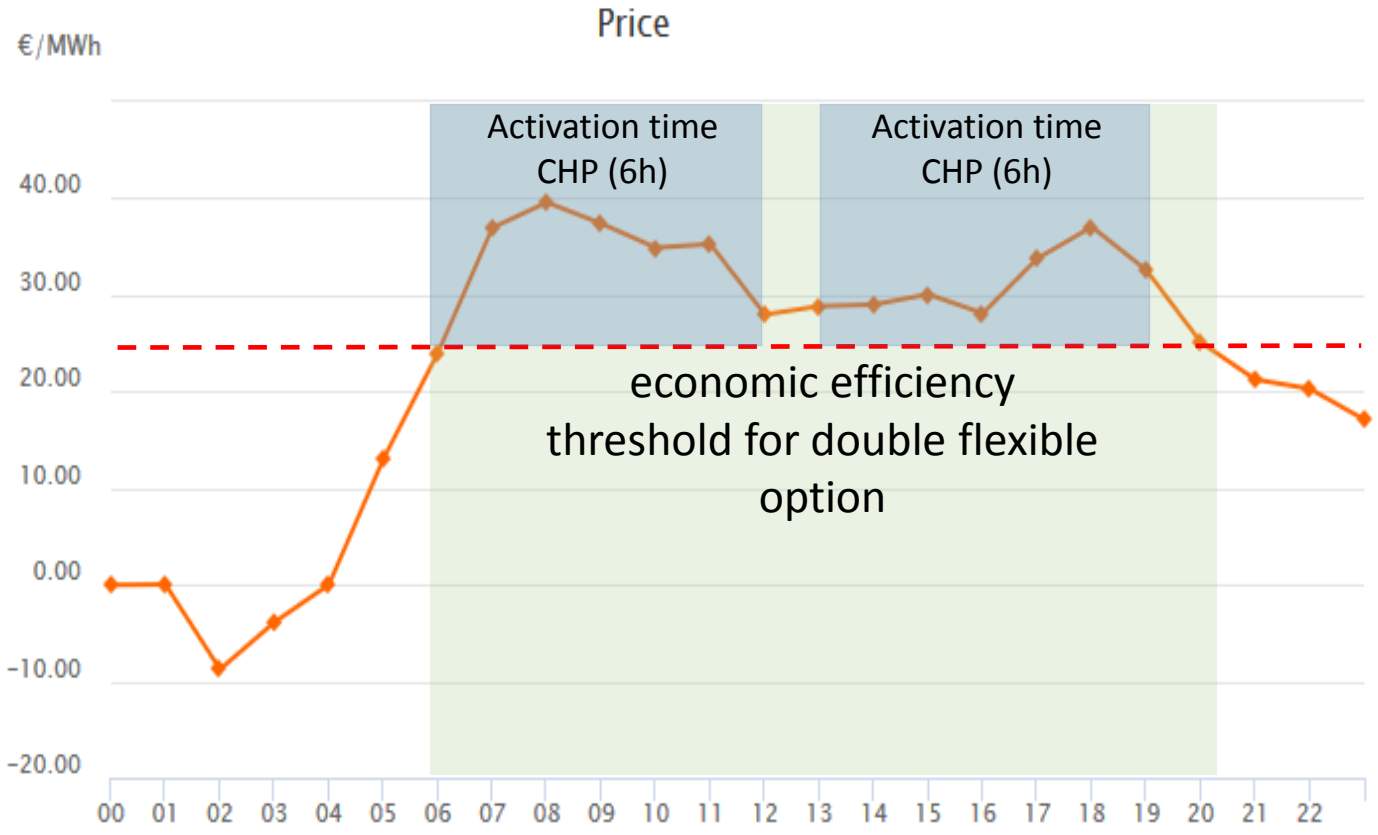
- Capex and opex for a given degree of flexible operation
    - Additional capacity installation
    - Additional maintenance effort
    - Costs related to decreasing capacity utilization
- Revenues and contracting conditions for the energy products
- Long term prognosis of the energy markets



Source: Barchmann, DBFZ

Economics of flexible operation

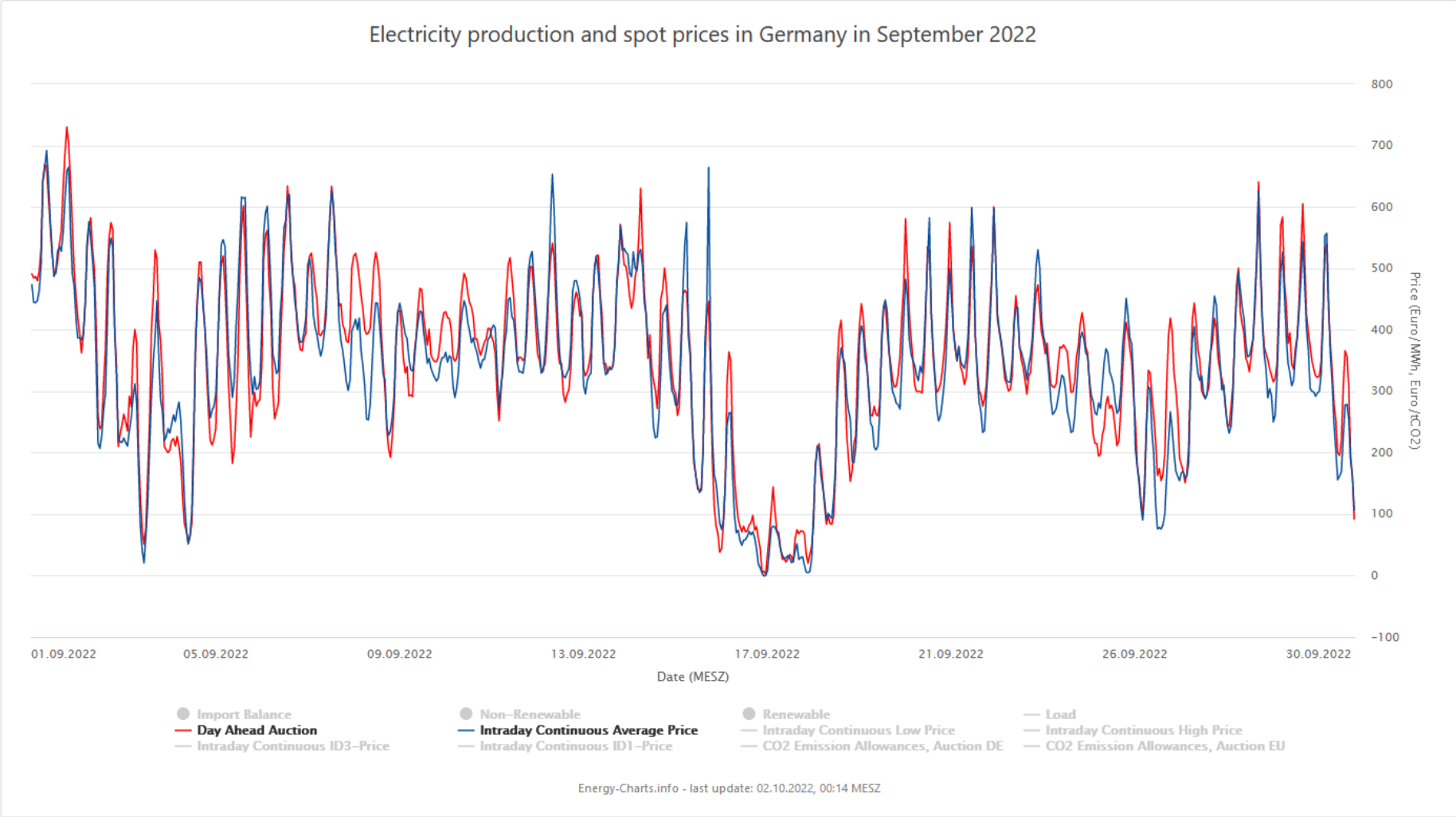
General economics – revenues of flexibilisation (market)



- 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

Example of daily price development of day ahead market in 2020 (Auction Day Ahead, 60 min, Germany, 31 of January 2020, Baseload (Source: EPEX SPOT))

Economics of flexible operation



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

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 m^3
- Heat storage of 1,000 m^3 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

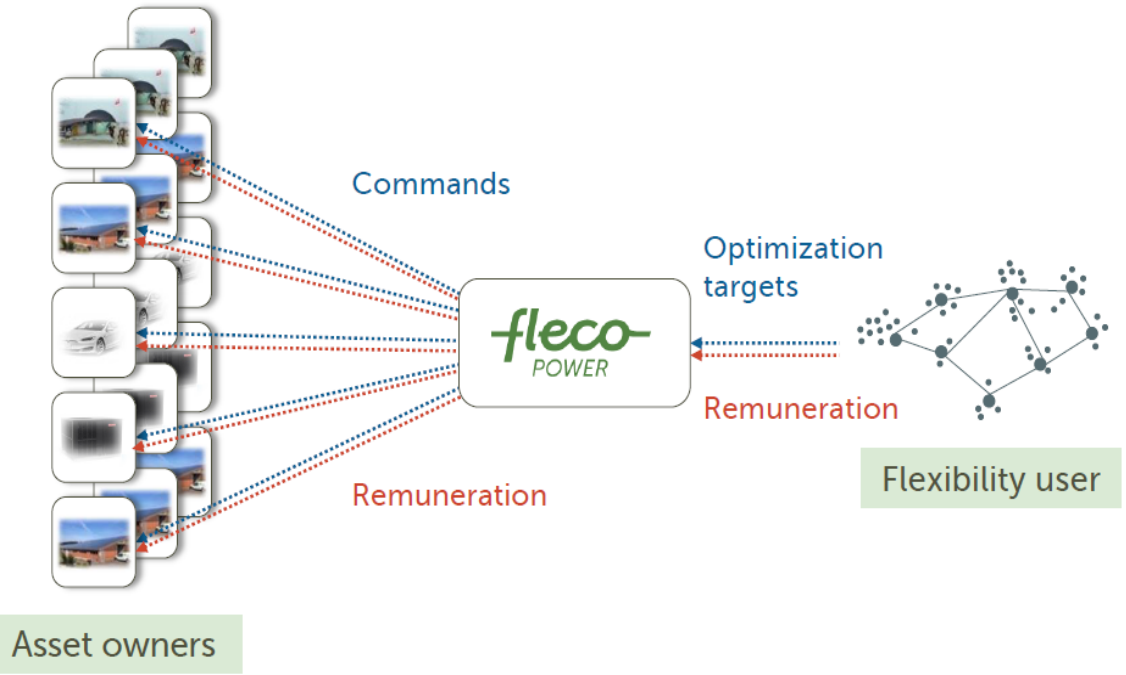
The Swiss virtual power plant "Fleco Power" represents a marketplace to match flexibility of producers and users of new renewable energy.
The flexibility of over 80 biomass, small hydroelectric and photovoltaic plants with a nominal power of 30 MW is bundled and marketed as control energy to Swissgrid, the Swiss electricity grid operator.

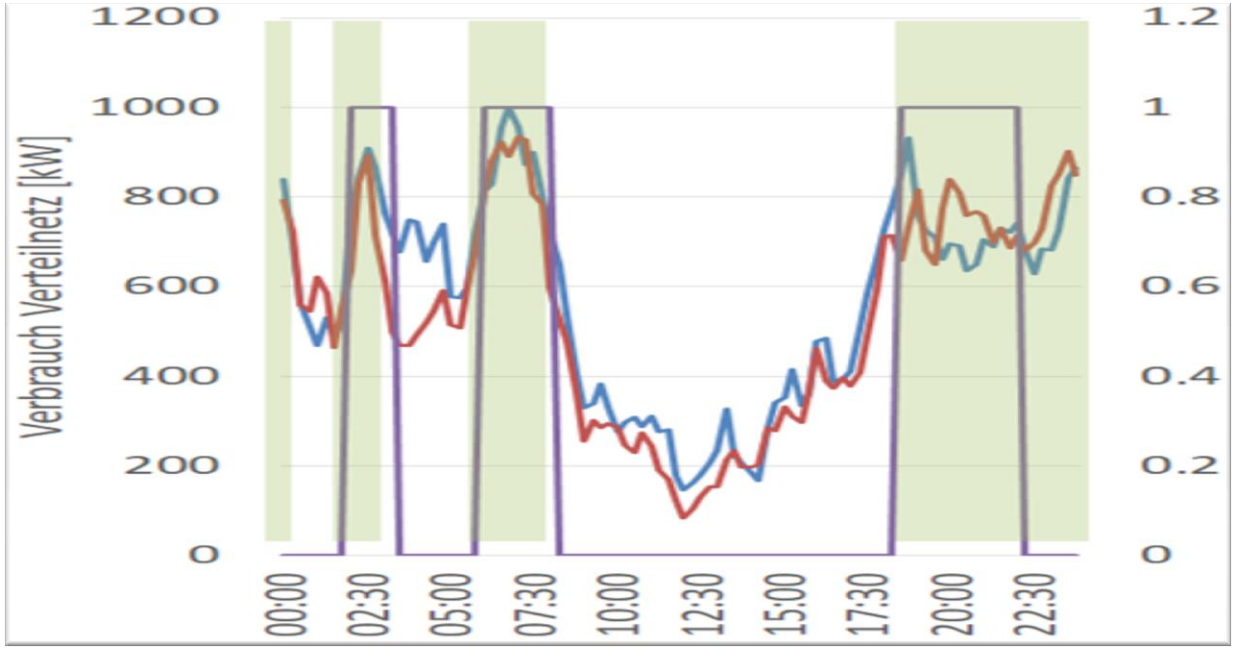
Fleco Power Structure to combine flexibility of decentralized installations

Source: IEA Bioenergy 2020

Exemplars of flexible operation

Flexibilisation in Switzerland – Virtual Power Plant





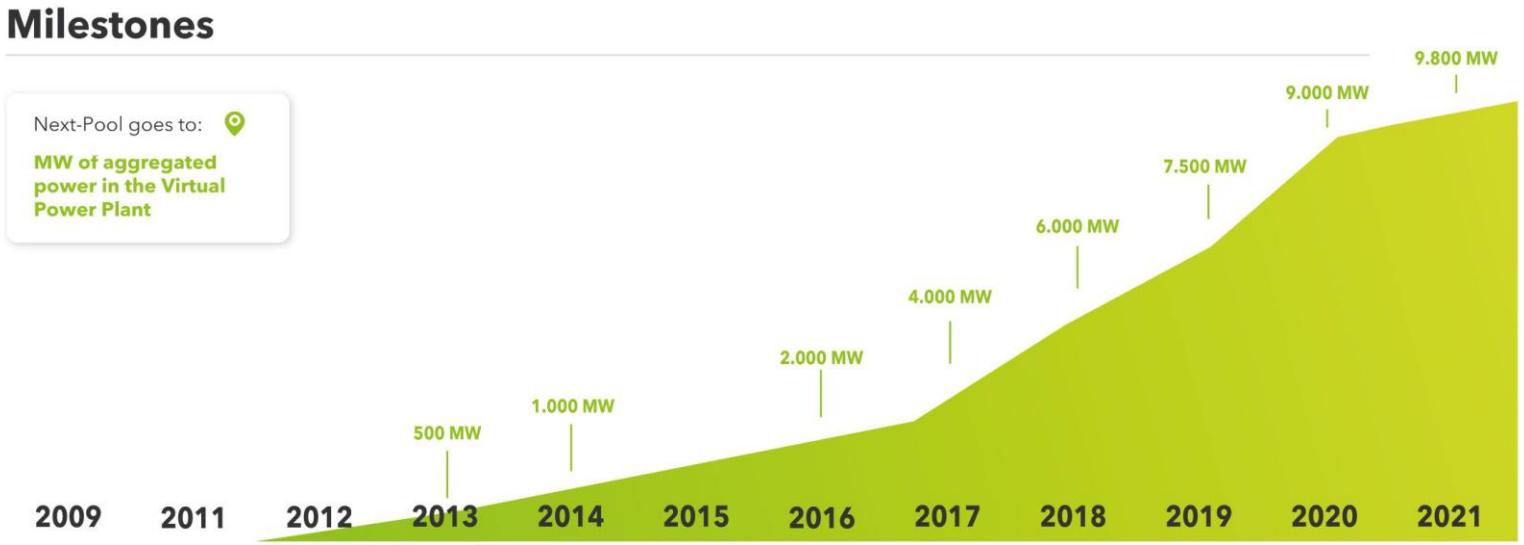
Example of a 1-day flexibility control time course of a biogas installation in Switzerland in Autumn.

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

violet: biogas CHP timetable

Source: IEA Bioenergy 2020

Virtual power plants – Exemplar in Germany



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

Company History Portfolio Development Next-Kraftwerke; https://www.next-kraftwerke.com/download-center?category=3

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;
- Biomethane directly to local consumers besides electricity and heat also 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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IEA Bioenergy: Task 37

August 2020

Technology Collaboration Programme
by iea

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

Thank you for your interest

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