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Integration of biogas systems into the energy system

Technical aspects of flexible plant operation

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Energy systems of the future

The climate emergency requires vast changes in how we produce and use energy. The **electricity sector** includes for ever increasing portions of intermittent renewable electricity such as from wind and photovoltaic (PV), neither of which are dispatchable. Innovation and ingenuity will be required by electrical utilities in matching supply to demand and in monitoring and control of grid frequency and voltage.

Producers and consumers of energy will face significant changes in the energy market, particularly associated with times of production of energy and times of use of energy. 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 need to cope with the changes in demand for energy over the day, the week or the season results in technical requirements for the energy supply system such as start up time, capacity increase and decrease rate, and time to shutdown. The requirements from different energy sectors or specific customers differ substantially.

Gas is also a major component of the **heat sector** both for district heating which is seasonal in nature and for industries which have a more constant demand but very large scale of energy requirement. Renewable gaseous fuels (including for hydrogen and biomethane) have great potential to decarbonise **transport fuel** use in haulage and intercity buses. The demand profile here depends on the logistics of the vehicle use and whether the renewable gas facility is situated adjacent to the filling station for the transport fleet or is at a remove from the transport fleet and uses the natural gas grid to serve gas to the transport fleet.

Flexibility of biogas systems

Flexibility in this report represents the ability of a biogas plant operator to control operation in a manner to best match the output of the biogas plant with the demand of the users of the

provided energy be they in the electricity, heat or transport sectors. Demand oriented, flexible operation requires a controllable and scalable interaction of all components of the biogas production and utilization process. The achievable degree of flexibility of the overall plant depends on the installed capacity of the components and the controllability and response characteristics of each component. Additionally the availability of storable feedstock for the biogas facility has to be considered when manipulation of the whole production chain is taken into account.

Biogas systems can also serve as a sink for electricity produced at a time of low demand and as such can reduce curtailment and constraint of intermittent renewable electricity. Hydrogen produced via electrolysis may be used to upgrade biogas to biomethane through the action of hydrogenotrophic methanogens which utilise hydrogen and carbon dioxide in the biogas to generate methane ($4\ H_2 + CO_2 = CH_4 + 2H_2O$). The process typically increases the methane output from a biogas facility by 70%.

Integration of the biogas systems into the energy system

Biogas is a versatile energy carrier which can be used to produce electricity, heat and after upgrading serve all functions of natural gas, including transport. Biogas systems are highly scalable in their energy output according to the demand from the particular energy sector. The flexibility of biogas systems can facilitate **electricity production** at a dynamic schedule to match an electricity demand profile, while facilitating voltage and grid stability. As a decentralised component of the overall energy system biogas systems can function as an infrastructure hub for local energy consumers in rural areas. Biogas can play an essential role (together with PV and wind) as part of a virtual power plant in local distribution energy grids. Biogas systems can operate as a biological battery in coupling the electricity and gas grids using surplus electricity to produce hydrogen to react with biogenic CO_2 in biogas producing biomethane and increasing the output of biomethane (typically by 70%).

Innovation and ingenuity will be required of biogas operators in future energy systems. This report highlights how the operator can match biogas supply and demand for energy as electricity, heat or transport biofuel across the larger future energy system.

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