GUIDE TO COOPERATIVE BIOGAS TO BIOMETHANE DEVELOPMENTS

PRODUCED BY

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Content

1. Introduction and Overview

Biogas upgrading and the production of biomethane nowadays is a state-of-the-art-process of gas separation. A number of different technologies to fulfil the task of producing a biomethane stream of sufficient quality to act as a vehicle fuel or to be injected into the natural gas grid are already commercially available and have proven to be technically and economically feasible. Nevertheless, intensive research is still in progress to optimise and further develop these technologies as well as to apply novel technologies to the field of biogas upgrading. All technologies have their own specific advantages and disadvantages and the selection of the most economic solution for a distinct AD plant site is not always straightforward. To facilitate project developments in that field, several reports and tools have been developed during the IEE-project Bio-Methane Regions. These documents comprise the "Biogas to biomethane technology review" and the "Biomethane calculator". The scope of the report at hand is to extend these information and guidelines towards possibilities of the joint or cooperative upgrading of biogas to produce biomethane.

As almost every technology, also biogas upgrading shows significant influence of the plant capacity on the specific costs of the product. As a result, the production costs of one cubic meter of biomethane significantly increases for every possible upgrading technology at plant capacity of 70m³/h of raw biogas or less. Thus, an economically feasible biogas upgrading cannot be performed anymore if plant sizes get too small. Figure 1 shows the economy of scale for different biogas upgrading technologies assuming an average raw biogas composition and upgrading for injection into the natural gas grid. Costs for the production of the raw biogas have been neglected. These results have been gained applying the named "Biomethane calculator".

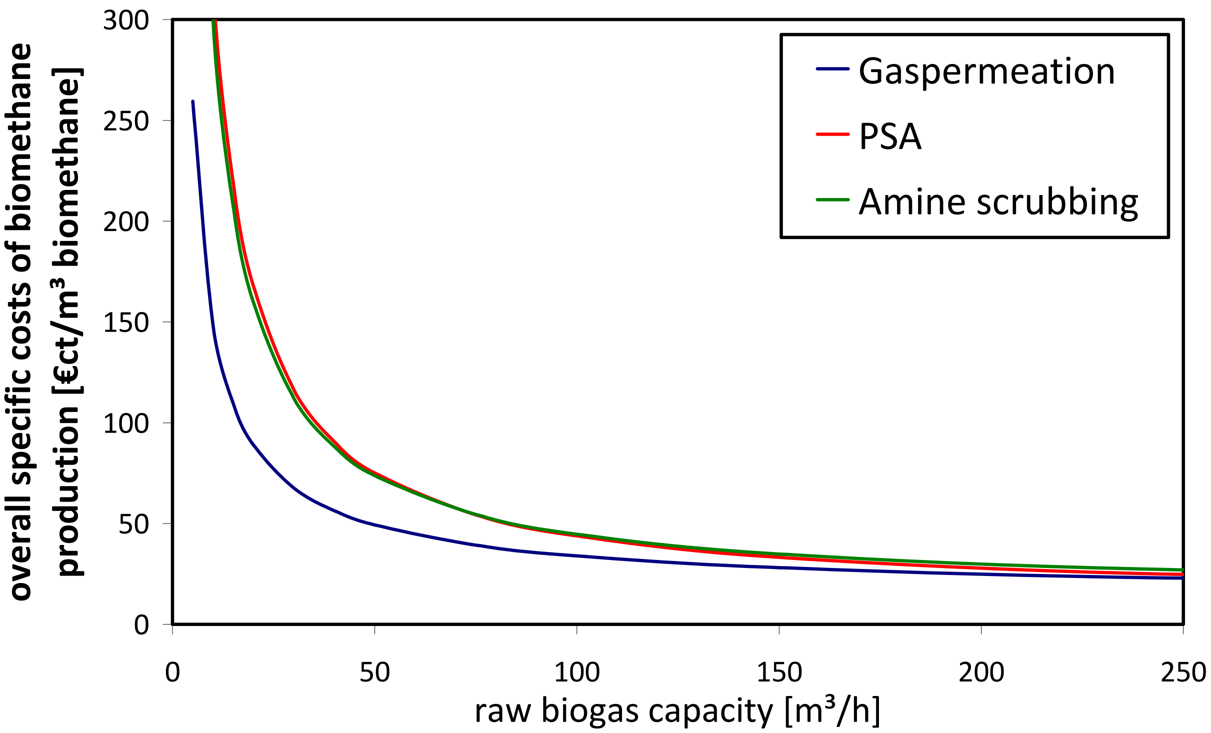

Figure 1: Economy of scale: degression of overall specific costs of biomethane production depending on raw biogas capacity for different biogas upgrading technologies

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Disregarding the absolute numbers in this figure, it is obvious that small AD plants cannot be complemented by a biogas upgrading unit economically. As we observe a multitude of plants of this size or even smaller, the question arises, if possibilities of cooperative production of biomethane can be found that allow for an economic overall operation. Joint upgrading of the raw biogas produced by a number of small-scale AD plants would take advantage of the economy of scale and would offer the possibility of choosing amongst a higher number of possible upgrading technologies. Furthermore, the maintenance and repairing of centralised upgrading facilities could be performed in a much more efficient way.

There is a number of different possible implementation of cooperative biogas upgrading which can basically be classified into two different concepts:

- A mobile gas upgrading unit of bigger size transported amongst the involved AD plants and operating a defined percentage of the day. This has to be accompanied by sufficient storage volume for raw biogas at the AD plant and mobile storage volume for the biomethane. Moreover, this solution implies significant requirements towards logistics.
- A raw biogas pipeline collecting the biogas from the decentralised AD plants and piping it to a centralised upgrading facility. In this case, at least a rudimentary upgrading has to be implemented onsite the decentralised AD plants in order to protect the pipeline from corrosion, clogging and fouling.

The third option of combining the decentralised small AD plants into one big centralised plant is not covered in this report. The possibility to fill the raw biogas to mobile storage tanks at the decentralised AD plants and to deliver them to a centralised upgrading plant has also been neglected for economic reasons. Due to the high carbon dioxide content of raw biogas the storage pressure is very limited in order to avoid undesired carbon dioxide condensation. Thus, the needed volumes for transportation are far too big.

2. Mobile biogas upgrading solutions

The first possibility to share a biogas upgrading plant amongst a number of smaller AD plants is to construct a mobile gas processing unit that can be transported from one AD plant to another. After connection to the plant, the gas upgrading of the raw biogas stored at the AD plant is performed and as soon as the raw gas storage is emptied, the upgrading plant is transferred to the next AD plant.

Figure 2 gives a schematic depiction of one possibility of mobile biogas upgrading for cooperative biomethane production. In this scheme, the decentralised AD plants have distinct raw biogas storage tanks and the biogas upgrading plant rotates between all cooperating AD plants. Additionally, a mobile biomethane storage system provides the possibility to deliver the produced biomethane to a remote point of biomethane utilisation.

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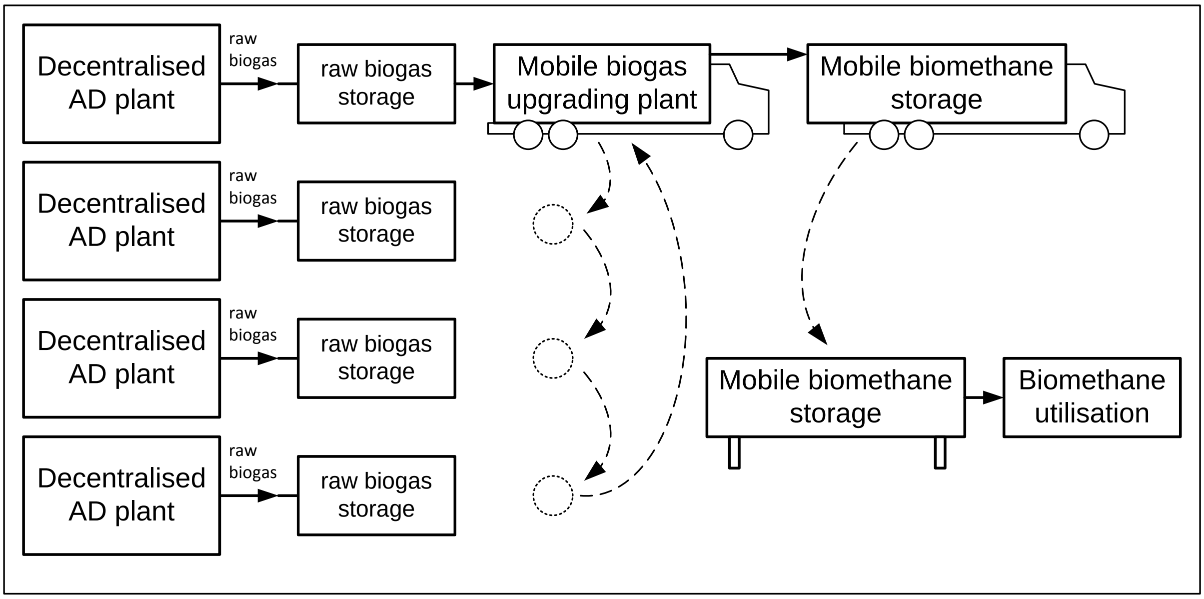

Figure 2: One possibility of mobile biogas upgrading for cooperative biomethane production applying mobile biomethane storage tanks; Source: Vienna University of Technology

First of all, a technology has to be found that is capable of:

- being constructed on a stand-alone mobile container implying low weight, low complexity and compact construction
- withstanding the strains of transportation (shock, temperature) and repeated assembling
- being capable of performing fast start-up and shut-down procedures, a start/stop-operation with high plant efficiency even at low operating temperatures
- being as cost-effective as possible as transportation means downtime, lowered plant utilisation and higher specific costs
- being capable to cope with different raw biogas qualities at the different AD plants regarding methane content and trace components

These constraints are very demanding and not many technologies currently available can be considered to be appropriate for constructing a mobile biogas upgrading unit. Typically, scrubbing upgrading units can be excluded due to complexity, absorbent handling and operating temperature. The same is true for cryogenic technologies or biological/biochemical systems. As a result, adsorption and membrane technologies remain from the technical point of view. Cost structure and start/stop-capabilities lead to the finding that the most suitable technology for a mobile application is membrane gas upgrading (gaspermeation). This biogas upgrading technology proves to be very cost-effective (especially for small-size units) and robust. The low level of complexity results in rather simple operation control and automation as well as high robustness and plant safety. Authors conclude that the most competitive mobile upgrading unit can be realised applying gaspermeation.

It has been shown, that it is possible to construct a complete biogas upgrading unit comprising compression, drying, final sulphur removal, carbon dioxide removal applying gaspermeation and high pressure compression within a standard 20-foot container. A scheme of such plant is depicted in Figure 3. The plant shown has been designed to meet a capacity of 300m^3/h of raw biogas which is already relatively big for a mobile application. As it can be seen, the major amount of space is taken by the two steps of gas compression. The overall weight of the complete container upgrading plant has been estimated to be in the range of 13 tons. Similar plants (although not mobile) have already been implemented in Austria and Germany.

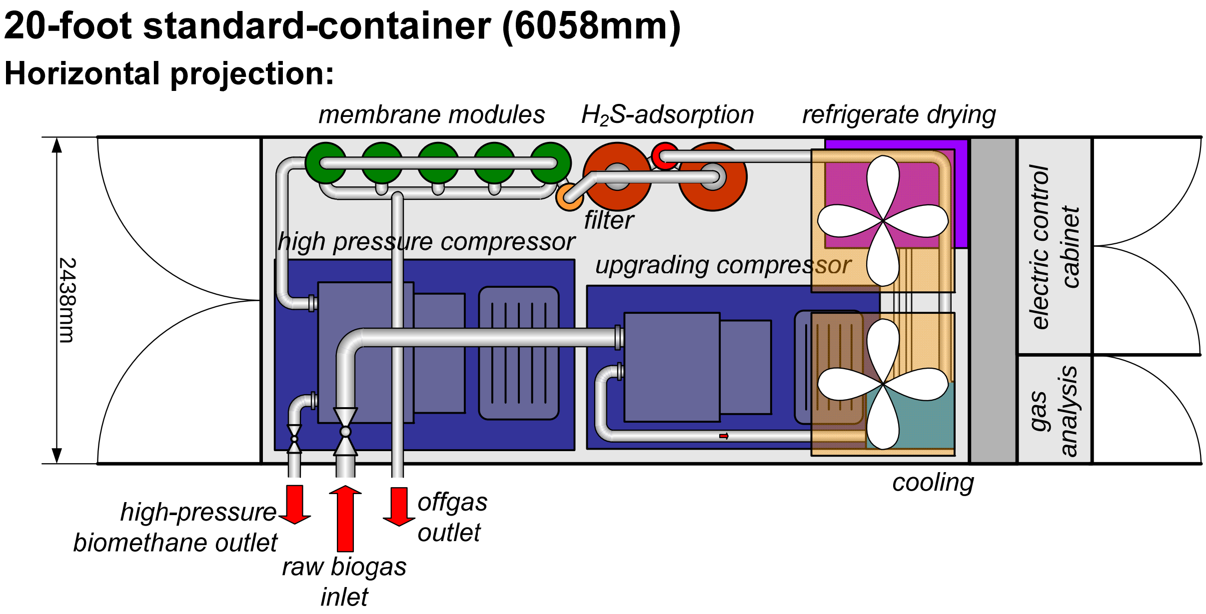

Figure 3: Scheme of a mobile biogas upgrading unit with a capacity of 300m³/h raw biogas using gaspermeation mounted in a 20-foot standard container; Source: Vienna University of Technology

The presented simplified plant layout neglects the need of processing the methane content of the offgas. Typically, a low calorific combustion or a catalytical oxidation is applied depending on the methane recovery of the biogas upgrading plant. It seems possible to adjoin such a system to the depicted upgrading concept.

Figure 4: Low pressure gas storage systems: balloon type gas storage (upper row left); cushion type gas storage (upper row right); membrane roof gas storage on fermenter top (lower row left); external double membrane storage system (lower row right); Sources: Sattler AG and Panaqua AG

Discontinuous operation of an upgrading plant at an AD plant of lower capacity necessitates the application of a storage tank for the raw biogas. Depending on the sizes of all cooperating AD plants and the biogas upgrading plant size an optimum size of this storage tank can be calculated depending on the planned frequency of plant migration. This storage tank can be operated at low pressure or at elevated pressure for improved storage volume utilisation. High pressure compression of raw biogas for storage purposes is unadvisable as carbon dioxide starts to condense at medium pressures already in raw biogas mixtures. The resulting two-phase mixtures are very disadvantageous for any storage concepts. Either way, low pressure will probably be economically favourable over medium pressure systems. Some commercially available systems of raw biogas capable storage systems are shown in Figure 4 and Figure 5. As low pressure gas storage of the raw biogas is very common and applied even at small-scale AD plants the application of this storage is not a basic problem. Nevertheless, the volume necessary to support a mobile and discontinuous upgrading plant will be significantly larger.

Figure 5: Raw biogas storage systems for elevated pressure: gas storage tank (left); compression and expansion unit (right); Source: Panaqua AG

The costs of raw biogas storage systems show to be in a very broad range even for similar concepts. Low pressure storage systems have prices starting at 20 €/m³ storage (simple cushion type storage by BAUR GmbH) up to 180 €/m³ storage (balloon and cushion type systems from companies like LIPP GmbH, MUCHE GmbH, ENTEC BIOGAS GmbH and AAT GmbH). Storage sizes of 500 to 2.000 m³ are common. Membrane roof gas storages on top of the fermenter or post-digester reside in the region of 25 to 55 €/m³ (BAUR GmbH). Storage systems for higher pressures are typically of much bigger size (50.000 to 250.000 m³STP) as the absolute investment costs are relatively high. The resulting specific costs are again in the range of 25 to 35 €/m³STP. To give a résumé, it can be shown that the influence of the raw biogas storage has significant influence on the overall economic feasibility. The costs for the system to be applied have to be assessed as precisely as possible during the performance of a feasibility study.

Additionally, as the point of utilisation of the biomethane might not be at the point of production, a storage tank for the produced biomethane will have to be applied. This tank has to be mobile and will frequently be transported to the site of biomethane utilisation. This site could be a grid access point where the biomethane is injected to the natural gas grid or it could be a fuelling station for (bio-) CNG vehicles. In order to facilitate fast, efficient and uncomplicated logistics of the produced biomethane the construction of the mobile gas storage system has to allow for fast load/unload procedures. There are several possibilities for pressurised gas tank transportation systems and many of these systems are already commercially available. Figure 6 gives an idea of possible solutions applying the WAB-system for flexible truck body configurations. These constructions typically are relatively cheap and flexible.

Figure 6: Pressurised gas tank transportation systems applying WAB system: design study of gas transportation truck with 150 cylinders of 80 litres volume for 220 bar (left); swap trailer system (mid); light lorry with swap trailer body (right); Source: Güssing Energy Technologies GmbH, Schoon Fahrzeugsysteme

Figure 7: Pressurised gas transportation system – the Galileo system “virtual pipeline”; Source: Galileo SA

Maybe one of the most mature systems currently available is provided by GALILEO SA, a company well known in the field of gas, CNG and oil handling. The system called “virtual pipeline” has been commercially launched in 1999 for fossil natural gas supply in remote regions or regions without natural gas grid. Figure 7 shows two pictures of this system including the loading/unloading of the modules. One of these modules holds up to 1.500 m³STP of gas. The Galileo system could perfectly meet the demands of flexibility and easy handling encountered in a wider network of remote biomethane production facilities.

One key to a successful operation of a mobile biogas upgrading solution is streamlined logistics. Together with a simple and standardised storage transport system the volume, pressure and transport frequency of upgrading plant and biomethane storage tank are crucial. These parameters have to be optimised for any new location of project realisation in order to achieve maximum efficiency and adequate economics. As the daily transportation time of upgrading plant and mobile storage tanks will be relatively low, outsourcing of this task to an extern transporting company seems to be advisable.

It has to be mentioned that transport of pressurised gas tanks on roads has to be compliant with the relevant legislative framework conditions of the country or region involved. Depending on the legislation, these conditions might involve the initial typification of the transport vehicle according to ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road), periodic inspection of the vehicle system and annual renewal according to ADR, inspection and certification of gas tank and piping (e.g. TUV), training and certification of the vehicle crew according to ADR.

Conclusion: To evaluate the most competitive solution of a mobile biogas upgrading concept the local circumstances have to be known very well. Especially the number and capacity of the involved AD plants, their production time schedule, the distances between these plants and the site of the biomethane production as well as the planned biomethane utilisation have to be assessed. After that, a well-founded techno-economic evaluation (for example by inclusion of “Biomethane Calculator”) of possible system configurations has to be performed to finally end up with the most suitable one. Feasibility studies show that an economic operation of such concepts is not easy to achieve.

Calculatory example: To give a brief impression of the boundary conditions to be expected we give a short numeric example of four small-scale AD plants forming a cooperation to jointly upgrade their raw biogas to produce biomethane. This case will be compared with the case of four distinct decentralised biogas upgrading plants using the same upgrading technology. We assume biogas upgrading for grid injection purposes (regarding gas quality) but we postulate that the grid injection point is not within pipeline vicinity. Thus, the produced biomethane will have to be compressed for transportation purposes to 220bar. This is true for the four decentralised upgrading plants as well as for the mobile upgrading plant. In both cases, we include the high pressure compression in our analysis but we leave out the high pressure storage and transportation of the biomethane as well as the grid injection point itself. Any costs for producing the raw biogas have also been excluded as these do not influence the comparison between the two cases. We have performed a short storage volume optimisation and we have set up a viable time schedule for the labour to be done (costs of raw biogas storage volume have been set to 50€/m³). The boundary conditions for this calculatory example are given in Table 1, the storage tank dimensions is the first result of the optimisation step which is focussing on minimum investment costs.

Table 1: Boundary conditions for calculatory example of cooperative biogas upgrading

	Cooperative biogas upgrading initiative			
	Plant A	Plant B	Plant C	Plant D
Raw biogas capacity [m³/h]	50	80	30	50
Raw biogas storage duration [h]	41	38	43	41
Raw biogas storage volume [m³]	2050	3040	1290	2050

The biogas of these four plants with a total capacity of 210 m³/h will be upgraded applying a medium-recovery gaspermeation upgrading plant of 300 m³/h size. The transportation schedule is set up to realise a cycle time of 48 hours (every plant is visited once in 48 hours). This means, two upgrading plant transportations have to be scheduled per day. The time schedule for this example layout together with the raw biogas storage tank filling levels is given in Figure 8. The transportation costs are estimated to be in the range of 2,7 €/km and the average distance between the AD plants is set to be 50 km with a transportation time of one hour. Machine set-up time is estimated quite conservatively to be one hour for connecting and disconnecting at the AD plant site. No labour is scheduled to be during the nighttimes.

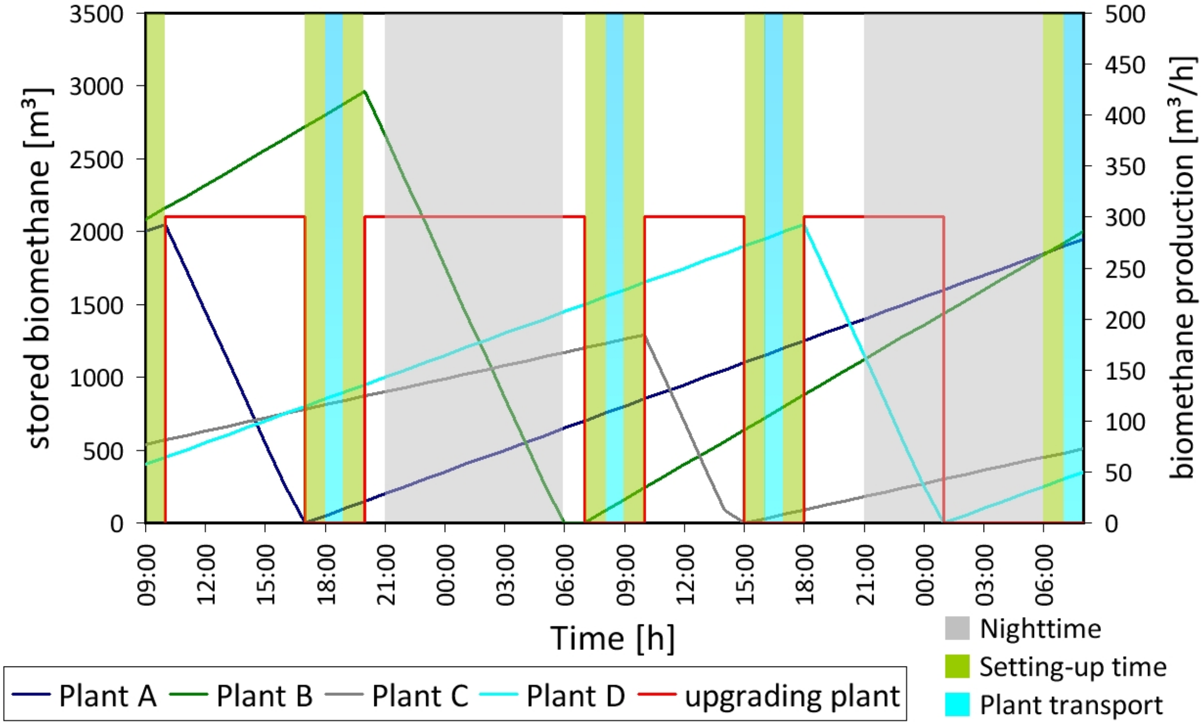

Figure 8: Time schedule of biogas upgrading plant handling 4 small-scale AD-plants including raw biogas storage tank filling levels; Source: Vienna University of Technology

The results of the short economic analysis done with the help of "Biomethane Calculator" are summarised in Table 2. Investment costs, annual costs (sum of capital costs for a depreciation period of 15 years, plant operation and plant transport where appropriate) and specific production costs per m³ biomethane are given.

Table 2: Results for calculatory example of cooperative biogas upgrading compared to decentralised biogas upgrading

	Cooperative upgrading	Decentralised upgrading
Investment costs upgrading plant	1 mobile plant: 1.292.819 €	Sum of 4 plants: 2.076.574 €
Investment costs raw biogas storage	Sum of 4 plants: 421.500 €	-
Considered total investment costs	1.714.319 €	2.076.574 €
Annual costs of transportation	98.550 €/a	
Overall annual costs including capital costs, operation and transportation	496.135 €/a	522.695 €/a
Specific production costs	43,7 €ct/m³ biomethane	59,2 €ct/m³ biomethane

These results seem to be quite promising as the cooperative upgrading initiative is able to produce biomethane at significant lower specific costs. The investment costs as well as the annual costs are also considerably lower. Of course, compared to one centralised AD plant (capacity of 210 m³/h raw biogas as the sum of the 4 small-scale plants) and one non-mobile centralised upgrading plant (specific biomethane production costs of 34,8 €ct/m³), the costs are still significantly higher. But the real problem results from the underlying time schedule. Two transportations of the upgrading plant means 730 transportations per year which adds up to extensive stress and wear of mechanical parts. With this background, the considered depreciation time of 15 years seems to be very unrealistic. If we consider a concept applying a plant transportation every second day (cycle time of 96 hours), the required raw biogas storage volumes would increase by a factor of about 2,87. As a result, the investment for this storage would jump from 421.500 € to 1.212.000 € and the specific production costs for the cooperative upgrading could be expected to be in the range of 67,9 €ct/m³ biomethane. Thus, the cooperative solution would be far more unattractive than the decentralised solution. Once again, it has to be stated, that economic feasibility of these concepts is very difficult to achieve and well-founded feasibility studies have to be performed in an early stage of the project.

3. Raw biogas pipeline and centralised biogas upgrading

The second possibility to share a biogas upgrading plant amongst a number of smaller AD plants is to connect the decentralised AD plants with the decentralised upgrading plant using a raw biogas pipeline. Compared to the first possibility of a mobile upgrading plant, this scheme allows for a much more flexible selection of the upgrading technology and a more precise dimensioning of the upgrading plant. Furthermore, the application of storage tanks for raw gas and product gas is not necessary anymore. On the other hand, as pipelines are expensive for higher distances compared to road transport, the pipeline solution is inefficient, if the distances between the decentralised AD plants are too big or if the transported volume flow of raw biogas is too small (as specific investment costs of a pipeline are almost not depending on the pipe diameter).

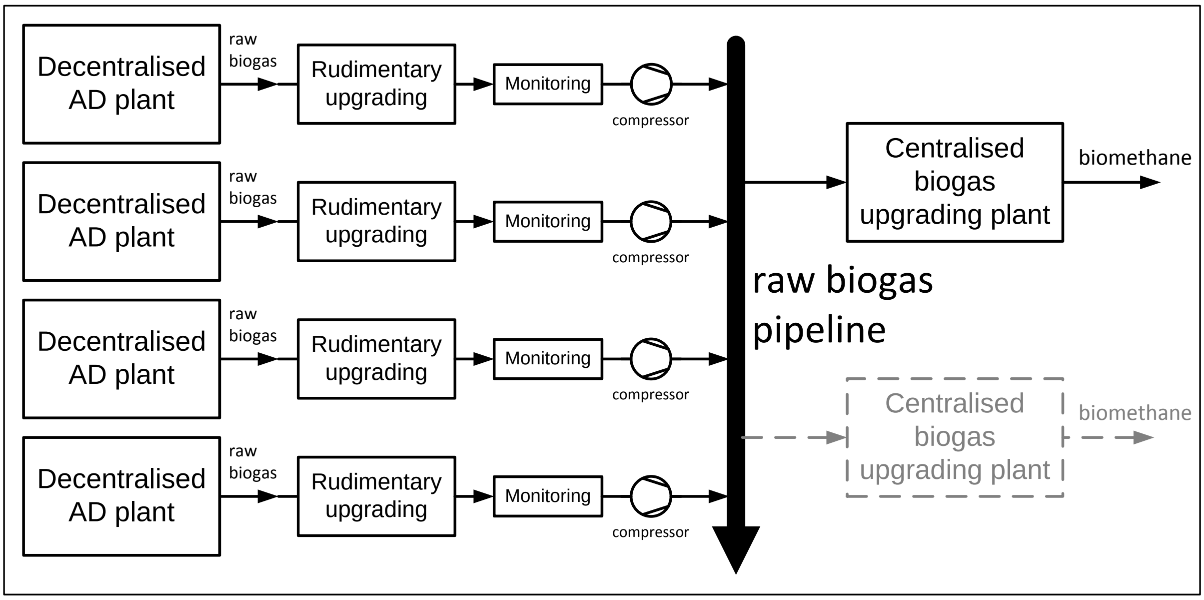

Figure 9: Scheme of cooperative biomethane production using a concept of a raw biogas pipeline and a centralised biogas upgrading unit (even more than one biomethane production plant is conceivable); Source: Vienna University of Technology

A schematic depiction of centralised biomethane production for decentralised AD plants applying a raw biogas pipeline is given in Figure 9. Depending on the design of the concept, not only one but even more biogas upgrading units can be applied.

The raw biogas pipeline would be designed to operate at a low gas pressure of around 200 mbar(g) to 2,0 bar(g) and would probably be made of polyethylene (PE). Just to get an idea of the pipeline dimensions we would suggest to use an inner diameter of 15 cm for a raw biogas volume flow of 1000m³STP/h. Calculations show that investment costs in the range of 120 to 200 € per m pipeline length would have to be anticipated. These costs would cover the pipeline for lying directly in the ground and also compressor stations and monitoring. The numbers are highly dependent upon local circumstances. Figure 10 shows the construction of the biomethane pipeline in Bruck/Leitha, Austria (certified for up to 10 bar(g)) comparable to raw biomethane pipeline systems.

Figure 10: Biomethane pipeline in Bruck/Leitha, Austria during construction; pipe connection by welding (right); Source: Vienna University of Technology

An important factor when operating a raw biogas pipeline is the conditioning of the fed in gas in order to avoid clogging or damaging of the pipeline. The most important step of conditioning is the drying of the raw biogas in order to avoid condensation in the pipeline. Liquid water within the piping system could directly lead to a blocking of the system or it could lead to frost bursting at exposed locations. Furthermore, as biogas is biologically active (microorganisms usually resident in the biogas fermenters are also transported in the biogas), liquid water would substantially promote biological fouling through the development of microbial lawns in the system again leading to a blockage of the piping system. Another important conditioning step comprises the removal of ammonia from the fed in gas as liquid water together with NH_3 causes corrosion of the metallic and polymeric parts of the system. A drying step by condensation of water prior to feeding the raw biogas to the pipeline would serve best in order to condition the gas as ammonia would simultaneously be removed. Applicable technologies for raw biogas water removal are: vapour-compression refrigeration, absorption refrigeration, drying by absorption with glycol (triethyleneglycol TEG), drying by adsorption on silica or Zeolithe. Efficient ammonia removal can be performed by contacting with liquid water (during refrigerate drying) or by adsorption on activated carbon.

Apart from water and ammonia the biogas may also contain other components that have to be removed from the gas prior to feeding it to the raw biogas pipeline. These components may contain hydrogen sulphide (some of the known initiatives planning raw biogas pipeline cooperative biogas upgrading define a maximum threshold of around 2000 to 3000 ppm H_2S for the injection), siloxanes, dust or high contents of volatile organic compounds like organic acids, fatty acids or terpens. If such crucial components are present in the raw biogas, the drying-by-cooling-steps might have to be complemented by additional adequate removal technologies. Please refer to the "biogas to biomethane technology review" for further information.

Finally, as the biogas has to be transported in the pipeline, a raw biogas compressor has to be applied to every site of biogas injection. As mentioned before, typical layouts of raw biogas pipelines assume an operating pressure of around 200 mbar(g) to 2,0 bar(g) whereas the production of biogas at the AD plant typically is a process under atmospheric pressure (or only slightly elevated). The specifications for these compressors are expected not to be very restrictive, a standard biogas compressor (or even only a blower) would be sufficient. Typically, compression is performed in two stages. After the first compression stage to an intermediate pressure, the raw biogas is fed to the aforementioned rudimentary biogas upgrading (as at least small over-pressure is needed there in most cases). The second stage compresses the biogas to the pipeline operating pressure. The following types of compressors are expected to be applicable for low- to medium-pressure raw biogas pipeline systems: rotary compressor, side channel or lateral channel blower, rotary piston compressor or reciprocating piston compressor.

The selection of the upgrading technology as well as the design and layout of the upgrading plant itself will be significantly easier compared to the mobile upgrading possibility. This is due to the fact that the upgrading plant will not have the very restrictive constraints of being mobile and having a highly discontinuous operation. Thus, any state-of-the-art upgrading technology may be applied for the production of biomethane from biogas of the raw biogas pipeline system. This results in a higher flexibility to adapt the whole energy production system to the regional circumstances.

Conclusion: As for the mobile biomethane production solution the local circumstances regarding possible plant sizes and distances, possible substrates for the biogas production and possible market spots for the produced biomethane have to be known very well in order to evaluate the most competitive overall concept. And also similar to the mobile solution, one general rule applies: the higher the number of small AD plants within a given area, the lower the transportation distances resulting in an improved economic situation. Again, after having assessed all relevant boundaries and parameters, a well-founded techno-economic evaluation (for example by inclusion of "Biomethane Calculator") of possible system configurations has to be performed to finally end up with the most suitable solution. Feasibility studies show that also for the raw biogas pipeline solution an economic operation of concepts of cooperative biomethane production is not easy to achieve.

Calculatory example: Additionally to the calculatory example provided for the mobile biogas upgrading solution we give an example for the raw biogas pipeline solution with similar assumption (where possible). Again we analyse the same small-scale decentralised AD-plants with a raw biogas capacity already given in Table 1 with the only difference that for each given capacity we double the number of plants to be considered (2 plants of type A, B, C and D respectively). A lower number of AD-plants would result in a change for the worse concerning the economics of cooperative upgrading. Additional raw biogas storage tanks as in the other scheme are not considered anymore. These eight decentralised AD-plants will be connected to a centralised biogas upgrading plant using a raw biogas pipeline. The centralised upgrading plant is designed to exactly meet the summed biogas capacity of the AD plants (no overcapacity). This case will be compared with the case of eight distinct decentralised biogas upgrading plants using the same upgrading technology. We assume biogas upgrading for grid injection purposes (regarding gas quality) but we do not account for the costs of the grid injection itself. This is to only show the influence of the upgrading plant size and the pipeline costs on the economics. Of course, if a real feasibility study is undertaken, these efforts will have to be taken into account, but at this point we want to omit additional economic effects introduced by different situations in grid injection. Any costs for producing the raw biogas have also been excluded as these do not influence the comparison between the two cases.

The biogas of the eight AD-plants with a total capacity of 420 m³/h will be upgraded applying a medium-recovery gaspermeation upgrading plant of exactly that size. Specific pipeline costs of 130 €/m length, a low pressure compression and a rudimentary upgrading involving refrigerate drying and ammonia reduction for each of the AD-plant's raw biogas have been considered. For the first analysis, a length of the raw biogas pipeline system of 20 km has been assumed.

The results of the second short economic analysis done with the help of "Biomethane Calculator" are summarised in Table 3. Investment costs, annual costs (sum of capital costs for a depreciation period of 15 years, plant operation and maintenance) and specific production costs per m³ biomethane are given. The last line of this Table gives the anticipated simple payback period for the cooperative biogas upgrading solution compared to the decentralised solution.

Table 3: Results for calculatory example of cooperative biogas upgrading compared to decentralised biogas upgrading

	Cooperative upgrading	Decentralised upgrading
Investment costs upgrading plant	1 plant: 1.062.390 €	Sum of 8 plants: 3.175.786 €
Investment costs raw biogas pipeline	2.600.000 €	-
Investment costs raw biogas compression	352.581 €	-
Investment costs rudimentary upgrading	257.501 €	-
Considered total investment costs	4.272.472 €	3.175.786 €
Overall annual costs including capital costs and operation	653.792 €/a	740.836 €/a
Specific production costs	37,0 €ct/m³ biomethane	42,0 €ct/m³ biomethane
Simple payback period	12,6 a	

These results seem to be quite promising as the cooperative upgrading initiative is able to produce biomethane at significant lower specific costs. Nevertheless, the significantly high investment costs for the construction of the raw biogas pipeline result in a relatively long payback period of almost 13 years compared to the decentralised non-cooperative upgrading scheme. If we consider a slightly shorter pipeline system of only 17 km, the pipeline investment costs would be reduced to 2.210.000 € and the simple payback period would be reduced to 6,3 years significantly improving the economic situation. We can conclude that the economic feasibility is highly sensitive to pipeline investment costs and this cost factor has to be assessed very carefully prior to a qualified feasibility study. Either way, compared to one centralised AD-plant combined with one central biogas

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upgrading plant at the same site, decentralised biogas and/or biomethane production is highly uneconomic.

Consideration of the distinct natural gas grid injection points would make the decentralised biogas upgrading applying a number of small-scale biomethane plants economically more unattractive compared to a cooperative upgrading solution with a single grid injection point. The influence of the investment costs (an also the direct operating costs) on the overall economics is expected to be marginal. The bigger problem is expected to arise from the organisational demand of handling the grid injection of a high number of small biomethane plants. Depending on the country and the stipulations given by the gas grid operator, the organisational procedure of feeding biomethane to a natural gas grid is typically fairly demanding (advance planning and notification, accounting and clearing*). As the labour needed for the accomplishment of these tasks is not depending on the biomethane feed-in capacity, higher numbers of small-scale grid injection points are economically unattractive.

4. Examples of cooperative biogas upgrading initiatives

There are a number of initiatives aiming at a cooperative upgrading of biogas mainly concerning small-scale agricultural AD-plants. Three different initiatives in different stages on their way to realisation will be shortly highlighted in the following.

Ringkoebing-Skjern biogas project, Denmark: The municipality of Ringkoebing-Skjern is the biggest municipality in Denmark with an area of 1.489 km². As a typical rural municipality it shows a high potential for biogas production. The municipality has initiated a public-funded pilot-project on the research whether the economics of biogas production and utilisation can be improved by transporting the biogas instead of the substrate. The plan is to establish around 60 small-scale and one or two large-scale biogas plants meeting the estimated potential of the municipality of around 60 million m³ methane per year. See Figure 11 for an overview of the geographical situation of the project. A raw biogas grid with a length of 150 km will connect these AD-plants with the existing CHP plants and one ore two biogas upgrading plants to be erected. The project will analyse the economics of two separate possibilities: 1) operating the existing CHP with raw biogas (revamping of existing gas engines and acquisition of new gas engines), upgrading and feeding the excess of biogas to the natural gas grid or 2) upgrading the entire quantity of biogas in two centralised biomethane plants and injection to the gas grid together with an unaltered operation of the existing CHP with natural gas from the grid. Additionally, the municipality has started research on storing the vast amounts of wind electricity as methane in the natural gas grid applying an electrolyser and a Sabatier-methanation of the produced hydrogen with carbon dioxide from biogas plants.

* clearing:
In banking and finance, clearing denotes all activities from the time a commitment is made for a transaction until it is settled. Clearing of payments is necessary to turn the promise of payment (for example, in the form of a cheque or electronic payment request) into actual movement of money from one bank to another. In trading, clearing is necessary because the speed of trades is much faster than the cycle time for completing the underlying transaction. It involves the management of post-trading, pre-settlement credit exposures to ensure that trades are settled in accordance with market rules, even if a buyer or seller should become insolvent prior to settlement. Processes included in clearing are reporting/monitoring, risk margining, netting of trades to single positions, tax handling, and failure handling. (source: http://en.wikipedia.org)

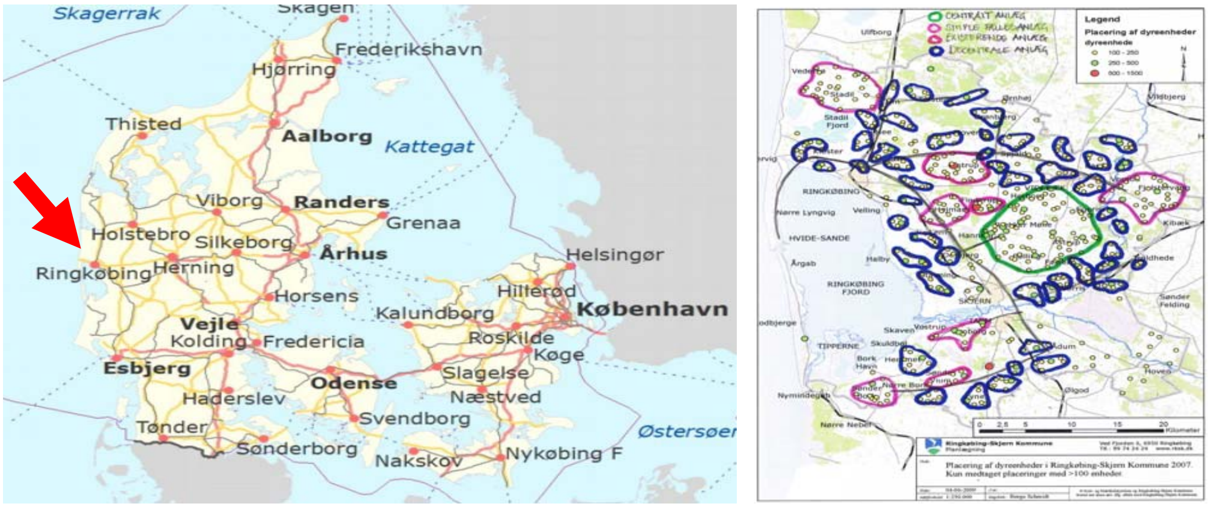

Figure 11: Location of the municipality Ringkoebing-Skjern in Denmark and geographical overview of the cooperative biogas project; Source: Bioenergi Vest A/S

More Biogas Småland AB, Sweden: In the municipality of Kalmar in the southern part of Sweden 18 local farmers, one producer of bio-methane (Famax AB), one public cleansing company consisting of 4 municipalities (KSRR) and a globally operating supplier of turnkey plants for biogas and biomethane (Läckeby Water) have started a limited company for the cooperative production of biogas. The foreclosed study analysed the option of building single AD-plants at each of the involved farms and to upgrade the produced biogas in a centralised biomethane plant connected by a raw biogas pipeline system. See Figure 12 for an overview of the geographical situation of the project. The focus was to utilise the produced biomethane as a fuel in the automotive sector. The outcome of this initial study was that the most economic solution for this particular region is the application of one centralised AD-plant and a transportation of the substrates (manure and organic waste) from the farms to the AD-plant. End of January 2013 the building of this centralised AD-plant with a capacity of 2 million m³/a has been announced. The plant construction starts in April 2013, final commissioning is scheduled for summer 2014.

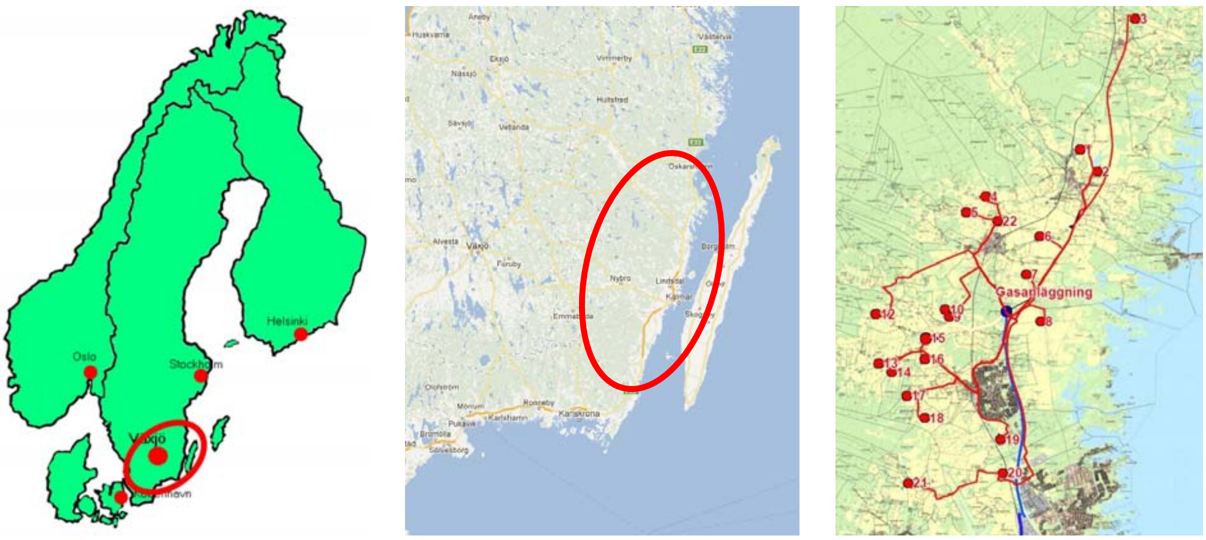

Figure 12: Location of the municipality Kalmar in Sweden and geographical overview of the cooperative biogas project; Source: Energikontor Sydost AB, LRF Konsult AB

Biogasnetz Guessing/Strem, Austria: The municipality of Guessing in the eastern part of Austria is considerably well-known for pioneering in self-sustained supply of various sorts of renewable energy carriers. A number of biomass-fired CHP-plants together with a district heating system provide the well-founded basis for further research projects. A woody-biomass based gasifier with a nominal capacity of 8 MWth is used for the combined production of electricity, heat and research on renewable energy carriers such as hydrogen, methane (SNG – synthetic natural gas) and higher hydrocarbons (by Fischer-Tropsch-systhesis). Additionally, an agricultural biogas plant using energy crops is in full operation. A research project evaluated the techno-economic feasibility of a biogas pipeline system of around 3,5 km length connecting the biogas producers (biogas from the AD-plant as well as SNG from the gasifier) with possible biogas consumers (CHP gas engines, CNG fuelling stations, companies with high natural gas demand). This biogas distribution system has been compared to decentralised CHP and a district heating system.