A SWOT on Biogas Grids

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Abstract—**Biogenic gases, such as biogas from anaerobic digestion and landfill gas, are not necessarily produced in locations that offer the best possible opportunities to valorise the gas at highest efficiency. Local or regional biogas grids, also referred to as micro gas grids for biogas, open the opportunity to transport biogenic gases from the location of their generation to a location with high-quality valorisation, such as combined heat and power production (CHP) with high usage of the heat component, or upgrading to biomethane as transport fuel or for injection into the natural gas grid. A SWOT analysis frames strengths and weaknesses of the approach, as well as opportunities, and possible factors that might constitute threats to a suitable implementation of biogas grids.**

Keywords- biogas grid; micro gas grid; electricity; heat; cogeneration; combined heat and power production (CHP); energy efficiency; biomethane

I. Introduction

Valorisation of biomass, in particular biomass that does not compete with food production, e.g. organic wastes and residues and biomass grown on marginal land, represents a key element in the transition to more sustainable and decarbonised energy systems that are largely based on usage of renewable sources [1]. Biogenic gases, comprising primarily biogas and landfill gas, are generated through biochemical biomass conversion, mainly anaerobic digestion (AD) in the absence of free oxygen. Landfill gas is an energy-rich gas (containing methane as energy-rich component) generated at landfill sites as result of degradation processes within the waste body; if captured, it can be valorised. Biogas is similar in composition to landfill gas, and it is generated through biochemically similar processes, but using anaerobic digestion technologies that are designed and actively operated for optimum biogas production.

AD with biogas production is a well-established technology with many thousand facilities in operation in Europe and worldwide [2]. Compared to other renewable energies, biogas production offers a range of advantages. Biogas production can directly make use of wet biomass such as liquid or semi-liquid residues or food waste, and the technology has a limited degree of complexity, which makes it also suitable for decentralized applications including in agriculture on single farms [3][4]. In contrast to other renewable energy technologies such as wind energy or solar energy, which are intermittent energy suppliers and in their energy delivery dependant among others on weather conditions, season and day time, anaerobic digestion can supply renewable energy continuously. In addition, biogas plants to some extent can be operated with flexibility to even better underpin and complement other energy forms [5]. The energy carrier biogas also offers the advantage that it can at least partially be stored in order to be used according to fluctuating demands or to availability of alternative energies.

Biogenic gases are usually valorised on-site to deliver electricity, heat or biomethane for transport or for injection into the natural gas grid [2][3][6][7]. AD is often placed in remote areas, among others to reduce odour nuisances. In Europe, AD plants are usually equipped with temperature control to ensure favourable digestion, and biogas plants without heating are very rare exceptions at single specific sites [8][9]. Therefore, AD plants have some heat consumption, however, the remote location of an AD plant often limits additional heat valorisation [10][11][12]. Furthermore, biogenic gases are often generated in decentralized mode, while high-value gas valorisation strategies require larger quantities of energy-rich gases.

As an alternative to on-site gas valorisation, biogas grids create the opportunity to transport the gases off-site to locations where the most efficient gas valorisation option can then be applied [6][7][13][14], including upgrading to biomethane or full use of heat generated along electricity production [15][16]. One specific advantage of such grids is that they can collect gases from several decentralized gas production sites, which can achieve economies of scale for high-value valorisation. This publication aims to provide a comprehensive assessment of challenges and chances of biogas grids. A SWOT analysis on biogas grids is presented to reveal associated strengths, weaknesses, opportunities, and possible threats.

II. Current Valorisation of Biogenic Gases

In some economically developing regions biogas is mainly generated in simple household-scale AD plants and largely used on-site for cooking and lighting. Throughout Europe, AD plants are usually operated at technically more advanced level and with more focus on achieving high gas yields. The size of such AD plants varies from decentralized farm-scale installations to centralized large plants at industrial scale. Generated biogas is valorised through different pathways:

- Generation of electricity
- Heat supply
- Fuel for cars/ vehicles
- Injection into the natural gas grid after upgrading

Landfill gas can be valorised through the same pathways. One difference however is that landfill sites usually have no or very limited heat demand, while AD plants themselves require heat to control the reactor temperature. Other heat consumers might be close to a biogas plant, e.g. the farm house at an agricultural AD generation site, while landfills are not usually located in direct proximity of housings or similar buildings.

Most common is electricity production with biogas (and with landfill gas), either for consumption on-site or for delivery to the electricity grid. Several engines can be operated with biogenic gases, based on thermal energy conversion processes (burning of energy-rich fuel) [3][10]. Occurrence of heat in addition to generated electricity is a technically unavoidable element in thermal energy conversion processes, and where it cannot be valorised it represents waste heat [17][18][19].

At biogas plants, electricity generation is often explicitly coupled with heat recuperation in combined heat and power plants (CHP), also called cogeneration, which increases overall efficiency due to valorisation of both electricity and heat (replacing other energy sources) [3][18]. Alternatively, the heat component can be used to provide cooling/ chilling (e.g. for agricultural storage facilities, pig stables, nearby hospitals), which achieves trigeneration or CHCP (combined heat, cooling and power production) [11][18][19]. Clearly, CHP or CHCP only achieves high overall efficiency if indeed a considerable demand for heat/ cooling exists and if demand patterns (seasonal demand, required temperature levels) match the generation patterns at the biogas site [18][20][21].

For small-scale AD facilities, heat-only generation (without electricity production) exists at some sites, where electricity generation cannot be achieved in an economically viable way. In such cases, similarly to CHP sites, overall efficiency is only high where indeed there is a corresponding demand for heat, and where the demand in quantity and in patterns matches the heat generation patterns of the biogas site.

Heat that cannot be consumed on site, can be delivered to consumers in the neighbourhood, using heat pipelines (steam hot water) to create a heat network. However, due to occurring heat losses, transport of heat (in contrast to transport of gas) is limited to rather short distances, typically few kilometres or less. The viable transport distance is context-specific and among others depends on temperature levels required by the consumers, the temperature level occurring at the heat generation site, costs of insulation, weather conditions, technical specifications to be considered [21][22].

In recent years, upgrading of biogas to biomethane with an elevated content of the energy-rich methane (CH_4) has been developed as an alternative gas valorisation [2][3]. Biomethane can be used to fuel transport vehicles or it can be delivered for injection into the natural gas grid after applying treatment steps that achieve a gas that complies with the relevant quality standards [23][24]. While different biogas upgrading technologies exist and are further developed, economic viability in practice usually requires larger gas volumes.

III. Biogas Grids

Biogas grids, transporting biogas and/ or landfill gas, enable implementation of complex gas valorisation strategies where the single elements do no longer need to be located within short distances from each other, and where economies of scale are achieved. The main applications of biogas grids, also referred to as micro gas grids, are shown with Figure 1.

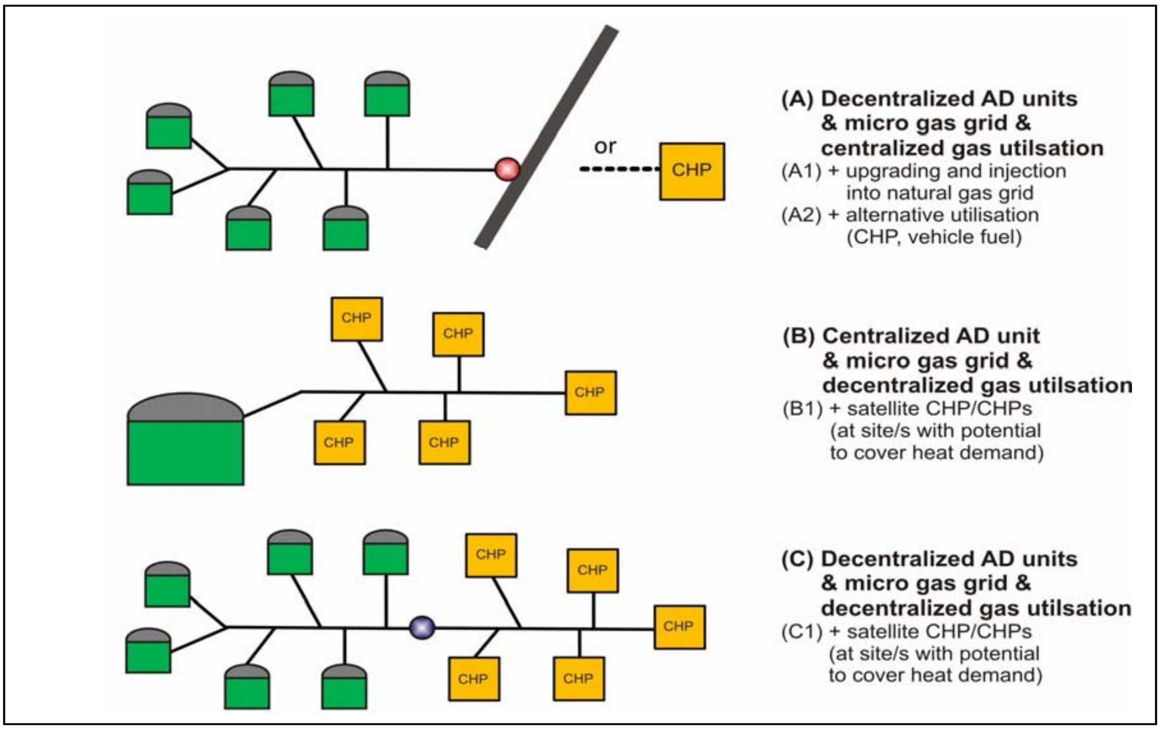

Figure 1. Main concepts for implementation of biogas grids [15] (partially based on [14] and [16])

As one main approach, biogas grids can be used to collect biogenic gases from different production sites (in general AD plants at smaller scale) in order to supply the gases to a central valorisation facility [7][14][16][25]. Such a centralized valorisation can be the upgrading of biogenic gases to biomethane and injection into the natural gas grid, the utilisation as vehicle fuel, or production of electricity with technical equipment that enables higher energy conversion rates compared to individual small-scale CHPs, and in best case in settings that achieve at the same time that much of the generated heat can be used as well [13][15].

The concept in which several biogas producers are connected via raw biogas pipelines to a central upgrading unit in order to gain economies of scale is referred to as 'Biogas Hub' in some regions and countries, for example in the Netherlands and Sweden [26].

Another main approach is to implement biogas grids to supply collected gases to individual sites (so-called satellite CHP units placed individually in direct proximity to the user) with high and continuous heat demand. This will assure that not only generated electricity is supplied to the grid, but also that energy present in the form of heat can be used. Considering the fact that at most AD plants heat requirement is rather limited much of the occurring heat remains unused, and consequently that it is one major drawback of the biogas technology that overall efficiency is much lower than possible, this is one smart concept towards increased sustainability and higher overall efficiency of AD [13][15].

The concepts A and B in Figure 1 (either centralized biogas production site or centralized biogas valorisation site) are more common choices, while the concept C is more challenging due to a higher degree of complexity [6][13][25]. Currently, in practice the operated biogas grids cover mainly the concepts A and B [25].

IV. Key Advantages and and Challenges of Using a Biogas Grid

Biogas grids can connect generators and users over longer distances, and furthermore create opportunities for alternative valorisation technologies with higher economic value. This can be assumed to usually be accompanied by environmental benefits, although progress in the current state of knowledge is required to better quantify achievable environmental benefits under different scenarios [7][13][27]. Clearly, not all possible applications of biogas grids prove to be environmentally advantageous [7]. General regulations, choice of technologies and site-specific implications influence the outcome, however, these factors need to be better framed and better understood.

The two key elements that improve overall efficiency of biogas valorisation are as follows [13][15]:

- Where biogas grids deliver the energy-rich gases directly to sites with heat demand, gas valorisation in CHP applications achieves increased overall energy efficiency degrees (making good use of electricity and heat) compared to direct valorisation on-site with limited usage of heat.
- Biogas grids create the opportunity to move from decentralized biogas utilisation to centralized technologies with higher energy conversion efficiency (upgrading of biogas for natural gas grid, biogas as vehicle fuel, electricity generation).

Therefore, biogas grids can increase economic viability of AD facilities, in particular decentralized AD plants. Compared to transport of heat, transport of biogenic gases via gas pipelines is far less complex and economically viable for significantly longer distances. When transporting gas, no heat insulation is required and only one pipeline is necessary to connect the location where gas is generated to where it is consumed (heat supply requires a two-way solution for circulating water).

With view to implementation of centralized gas valorisation, such as upgrading to biomethane, it is a distinctive advantage of biogas grids that they can collect sufficient volumes of biogas to allow for economically viable biogas treatment, while the actual biogas production can be kept at a decentralized level. This reduces transport of substrates and digestates and, due to its size, the biogas plant and its operation are easier to be integrated at farm level [13]. Decentralization also fosters community-based renewable energy generation [28][29][30]. This however does not generally mean that decentralized biogas production is environmentally more beneficial than centralized biogas production [7].

While biogas grids open new opportunities, on the other side they also mean that some additional technology and control is required, including additional safety measures [6][7][25][26]. Additional elements also mean additional consumption of electricity [27], which can reduce total economic and environmental benefits.

Overall, from the technical point of view, biogas grids are elements with a limited degree of complexity, and information about successful operation is available from a range of pioneering installations in practice [6][7][25][26], although the information currently remains limited. Knowledge gaps still exist, including knowledge about risk management [26].

As one element to be considered, some biogas storage is needed to cope with fluctuations in biogas generation or biogas utilisation. However, when suitably implemented, the biogas grid itself can provide storage capacity, which increases the value of biogas as a flexible energy carrier.

It also needs to be considered that when diverting biogas to another site to be valorised, temperature control of the anaerobic digester will still require some heat at the location of the biogas installation. Usually, some biogas will therefore still be valorised on-site to cover the heat demand (and where suitable also the electricity demand) of the anaerobic digester and its direct infrastructure. Placement of a small-scale CHP in direct proximity to the AD facility itself, while the largest share of biogas is being diverted to centralized valorisation, is a common and suitable solution.

Aside of more widespread technical and managerial knowledge about biogas grids, implementation of favourable

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frameworks is the most essential driver to a more widespread and sustainable adoption of this intelligent technology [13][15]. Biogas grids are not usually considered elements of the connected renewable energy generation facilities, but are rather seen as infrastructure, which implies that they might not be covered by funding programmes or grants that aim at more widespread uptake of renewable energies. Similarly, among others, attention should be paid to ensuring that prioritised remuneration schemes for renewable energy (e.g. feed-in tariffs for electricity from biogas) include valorisation of biogas at remote sites after supply via gas grids [13].

There is also generally a lack of specific regulation for biogas networks; often the regulations for natural gas networks are imposed, which might not be fully compatible [26].

Clearly, implementation of local or regional biogas grids has high potential to establish beneficial links between urban areas with energy demand and peri-urban or rural areas suitable for operating anaerobic digestion plants; therefore, one of the added values of the implementation of biogas grids is that they strengthen urban-rural interactions and furthermore that they create the opportunity to bring bio-energy in the form of biogas into urban areas [13]. Benefits exist for both urban and rural sites, economically but also with view to long-term positive development.

V. SWOT Analysis

Taking into consideration the possible advantages but also the existing challenges of biogas grid implementations, the SWOT analysis in Figure 2 brings together the central issues in this context. The presented analysis can be used to further elaborate strategies for suitable implementation of biogas grids, and furthermore, to attract policy support to foster favourable frameworks.

As one result of the SWOT analysis it can be deducted that more clarity is required about economic viability of different scenarios, and that potential bottlenecks (both of technical and economic nature) need to be explored in more detail. Favourable regulatory frameworks will be one of the most decisive elements to influence more widespread uptake of biogas grids in future. The risk that biogas grids fall between policy fields with an unfavourable outcome needs special attention.

The most promising outlook for biogas grids appears to be with scenarios that value highly flexible solutions and/ or with scenarios that foster decentralized production of renewable energy. Both aspects are elements of a more diversified energy sector.

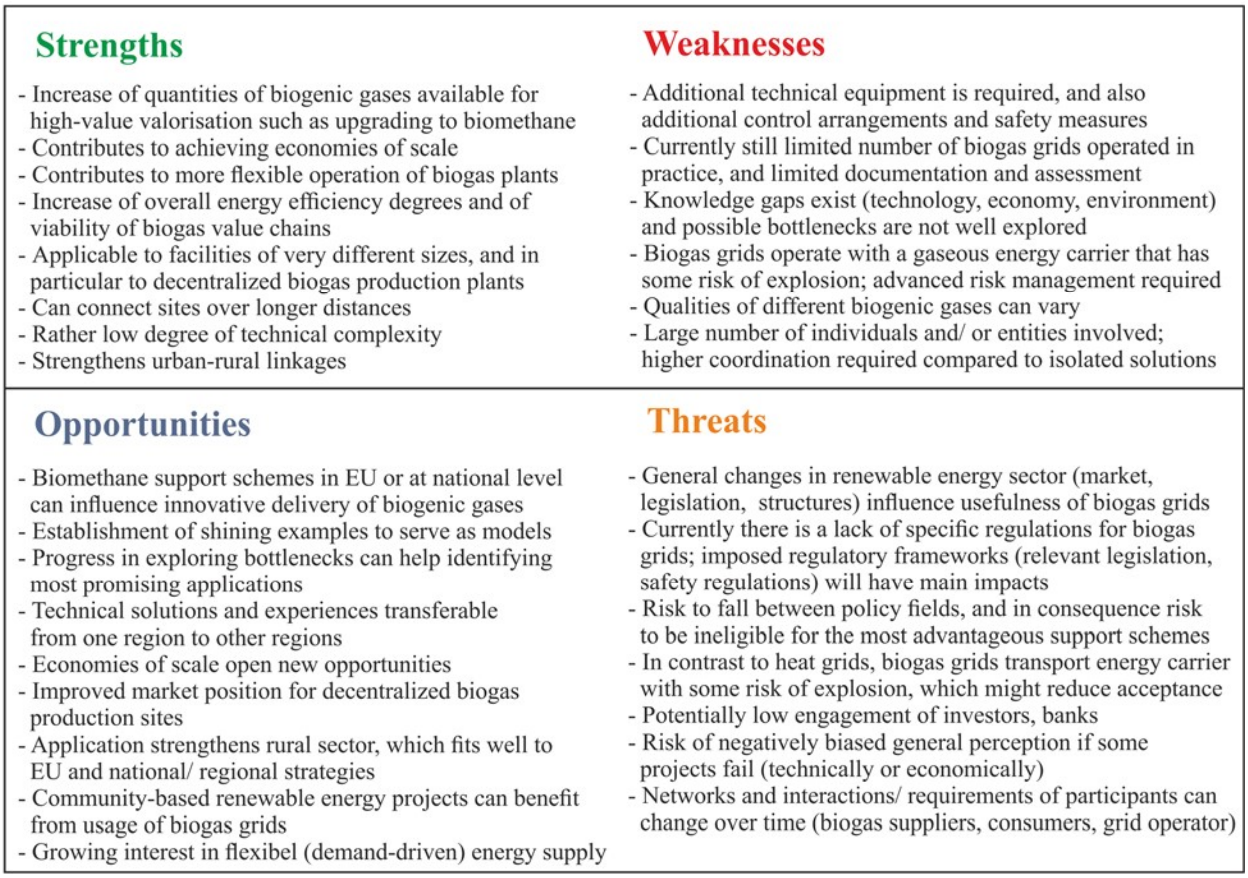

Figure 2. SWOT analysis of biogas grids

VI. CONCLUSIONS

Biogas grids can be particularly intelligent solutions to deliver biogenic gases (biogas, landfill gas) to where they can be valorised at highest efficiency, which increases overall sustainability of the value chain of biogenic gases. Biogas grids can increase economic viability of AD facilities of all sizes and can achieve environmental benefits.

Barriers for more widespread implementation seem to be the result of a currently limited knowledge base that still has gaps, and of the still limited number of operations in practice that are documented in suitable detail. Economic viability of different scenarios also needs more detailed assessment. In particular, a comprehensive and diversified assessment of possible bottlenecks, at both technical and economic level, is not yet available. Knowledge gaps also exist with view to environmental implications.

Determined, reliable and coherent policy support and introduction of favourable regulatory frameworks are required to overcome existing barriers. Biogas grids risk to fall between policy fields and to remain ineligible for the most favourable support schemes granted for renewable energy generation, since the biogas grids are often regarded as infrastructure rather than as part of the energy production. In particular, biomethane support schemes should integrate biogas grids; delivery of biogas from decentralized production sites to centralized gas valorisation facilities, such as upgrading to biomethane, increases the quantities of gas available for high-value valorisation, and contributes to achieving economies of scale.

One distinctive advantage of biogas grids is that they further increase flexibility of biogas production sites with view to making the energy carrier available when there is the corresponding demand for energy, in particular for electricity and heat. Such flexibility strengthens the position of biogenic gases in future energy systems.

REFERENCES

[1] International Energy Agency (IEA), Global energy transformation – A roadmap to 2050, IEA publication, Paris, 2018.

[2] N. Scarlat, J.-F. Dallemand, and F. Fahl, “Biogas: Developments and perspectives in Europe,” Renewable Energy 129 (part A), pp. 457-472.

[3] A. Wellinger, J. Murphy, and D. Baxter (edts.), The biogas handbook, Woodhead Publishing Series in Energy, Woodhead Publishing, 2013.

[4] T. Pullen (edt.), Anaerobic digestion – Making biogas – Making energy, Routledge, London, 2015.

[5] M. Lauer, and D. Thrän, “Flexible biogas in future energy systems—Sleeping beauty for a cheaper power generation,” Energies 11(4), 2018, no. 761.

[6] J. Bärnthaler, H. Bergmann, D. Hornbachner, G. Konrad, V. Kryvoruchko, L. Targyik-Kumer, C. Pinter, and C. Wartha, Gasversorgung mittels lokaler Biogas-Mikronetze, Bundesministerium für Verkehr, Innovation und Technologie, Vienna, 2009. (in German)

[7] E.J. Hengeveld, J. Bekkering, W.J.T. van Gemert, and A.A. Broekhuis, “Biogas infrastructures from farm to regional scale, prospects of biogas transport grids,” Biomass and Bioenergy 86, 2016, pp. 43-52.

[8] S. Kusch, and H. Oechsner, “Vergärung landwirtschaftlicher Substrate in Feststofffermentern,” in Fachagentur Nachwachsende Rohstoffe (FNR) (edt.), Trockenfermentation - Evaluierung des Forschungs- und Entwicklungsbedarfs. Gülzower Fachgespräche, vol. 23, 2004, pp. 105-113. (in German)

[9] S. Kusch, Methanisierung stapelbarer Biomassen in diskontinuierlich betriebenen Feststofffermentationsanlagen, PhD thesis, University of Hohenheim, Herbert Utz Verlag, Munich, 2007. (in German)

[10] D. Deublein, and A. Steinhauser (edts.), Biogas from waste and renewable resources: An introduction, Sscond edition, Wiley ‐ VCH Verlag, 2010.

[11] M. Köttner, S. Kusch, A. Kaiser, D. Dörrie, and D. Collins, Economic modelling of anaerobic digestion/ biogas installations in a range of rural scenarios in Cornwall. Cornwall Agri-Food Council, 2008.

[12] Fachagentur Nachwachsende Rohstoffe (FNR), Guide to Biogas - From production to use, FNR, Gülzow, Germany, 2012.

[13] S. Kusch, “Biogas grids – An intelligent element in efficient utilisation of renewable energy,” ARSA Advanced Research in Scientific Areas 2012, pp. 1823-1826.

[14] R. Erler, „Dezentrale Biogasnetze,“ Proceedings „Gastechnisches Kolloquium“ of DBI/ Gastechnologisches Institut in Freiberg, Germany, 2009. (in German)

[15] S. Kusch, M. Azodanloo, A. Frank, G. Hafner, J. Bachler, and M. Kranert, “Interdisciplinary approaches to advances in sustainable biogas production in Europe,” Proceedings of the International Congress “Progress in Biogas II – Biogas production from agricultural biomass and organic residues” in Stuttgart, 2011, pp. 52-55.

[16] J. Krassowski, and W. Urban, „Biogaseinspeisung in Erdgas-/Mikrogasnetze – Möglichkeiten und offene Fragen,“ Proceedings „11. NRW-Biogastagung“, Frauenhofer UMSICHT, 2010. (in German)

[17] International Energy Agency (IEA), Co-generation and renewables, IEA publication, Paris, 2011.

[18] S. Kusch, “An overview concerning combined heat and power production: a smart way to improve energy efficiency,” CSE City Safety Energy 2-2015, 2016, pp. 132-141.

[19] International Energy Agency (IEA), Heating without global warming, IEA publication, Paris, 2014.

[20] Carbon Trust, Introducing combined heat and power (Technology guide), Carbon Trust, London, 2010.

[21] S. Kusch, “Cogeneration (combined heat and power production) in Europe,” RCITD Research Conference in Technical Disciplines 2017, pp. 52-55.

[22] S. Kusch, “Common challenges in the implementation of combined heat and power production (CHP),” SGEM 2018, 18th International Multidisciplinary Scientific Geoconference, Slowakia, 2018. (in press)

[23] Fachagentur Nachwachsende Rohstoffe (FNR), Biomethane, FNR, Gülzow, Germany, 2013.

[24] F. Graf, and S. Bajohr, Biomethane: Production, upgrading and injection, Deutscher Industrieverlag, Germany, 2nd edition, 2016.

[25] O. Panic, G. Hafner, M. Kranert, and S. Kusch, „Mikrogasnetze - eine innovative Lösung zur Steigerung der Energieeffizienz von Vergärungsanlagen,“ energie wasser-praxis, no. 2/2011, pp. 18-23. (in German)

[26] R.N. van Eekelen, E.A. Polman, H.A. Ophoff, and M. van der Laan, New Networks for Biogas,Current Practices, Risks & Costs Aspects. Kiwa Gas Technology, Apeldoorn, the Netherlands, 2012. www.sgc.se/ckfinder/userfiles/files/SGC264_English.pdf (accessed 21 June 2018)

[27] E.J. Hengeveld, Biogas transport grids – Case study “Province of West-Flanders”, presentation slides Energy Academy Europe, 13.11.2017.

[28] G. Beggio, and S. Kusch, “Renewable energy cooperatives: main features and success factors in collectively implementing energy transition,” Quaesti Virtual Multidisciplinary Conference 2015, pp. 233-237.

[29] E. Viardot, “The role of cooperatives in overcoming the barriers to adoption of renewable energy,” Energy Policy 63, 2013, pp. 756-764.

[30] G. Cowtan, Community energy: A guide to community-based renewable-energy projects, Green Books, The Local Series, UK, 2015.