The potential for low-carbon renewable methane in heating, power, and transport in Belgium

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Introduction and policy background

This study presents the production potential for renewable methane in Belgium in 2050, drawing upon the European Union-wide methodology and assessment developed by Baldino, Pavlenko, Searle, and Christiansen (2018b). Belgium is in the process of developing its domestic energy and gas infrastructure policies necessary to comply with both the recast Renewable Energy Directive (RED II) and its Paris Agreement commitments. This study is intended to provide an independent estimate of the renewable methane potential in the country and the cost of greenhouse gas (GHG) reductions through increased renewable methane deployment through 2050.

As part of the Paris Agreement, Belgium has committed to reducing its GHG emissions by 80% of 1990 levels by 2050, including a closer-term target of a 40% reduction by 2030. This amounts to a total reduction of more than 100 million tonnes by 2050. Given the forthcoming decommissioning of Belgium's nuclear generation capacity in 2025, it is likely that Belgium may increase its reliance on natural gas in the near term as a transitional fuel source (Elia, 2017). Meeting those climate targets could necessitate greater reliance on alternative, low-carbon gas sources such as renewable methane. However, there has been relatively little policy implementation at the federal level to incentivize changes to Belgium's gas market; existing incentives for renewable methane production exist primarily on the regional level and renewable methane provides only a small share of Belgium's total gas consumption, providing only 1.6% of the 16 billion cubic meters consumed annually in 2015 (Scarlat, Dallemand, & Fahl, 2018).

To facilitate Belgium's long-term energy transition, it is necessary for policymakers to understand the extent to which renewable methane can replace natural gas over this time frame. This study assesses the long-term potential to produce renewable methane, and the associated production costs, in Belgium by 2050. In addition, the potential contribution of renewable methane to Belgium's electricity, heating, and transport sectors is assessed, identifying the extent to which it can contribute to the country's policy targets. This study also estimates the greenhouse gas (GHG) reduction potential from renewable methane and puts this opportunity in perspective with Belgium's Paris Agreement commitments.

Assessment methodology

This study estimates the total theoretical potential for renewable methane production in Belgium in 2050 across a variety of feedstocks and fuel conversion technologies. The methodology used in this paper is the same as in Baldino et al. (2018b), which assessed renewable methane production potential for the European Union. The renewable methane production potential estimated here includes current renewable methane production in Belgium of 250 million cubic meters annually, based on 2015 data, which is approximately 9.5 TJ of energy (Scarlat et al., 2018).

Three renewable methane conversion pathways are assessed, including anaerobic digestion, gasification of wastes followed by methanation,

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and power-to-gas, in which electricity is used to create syngas which is then converted to methane. Only the production of renewable methane from sustainable, low-carbon feedstocks that provide substantial GHG savings compared to natural gas is assessed. Baldino et al. (2018a) provides greater clarity on the reasoning behind the selection of feedstocks for this assessment. Table 1 lists the technology pathways assumed for each type of sustainable feedstock in our assessment, as well as the assumed GHG intensity and references for each pathway.

For the use of renewable methane supplied for heating and transportation, methane is assumed to first be injected into the grid. It is further assumed that renewable methane used for electricity generation is combusted on-site at the renewable methane production facility and that the electricity generated is carried through the electricity grid. In Baldino et al. (2018), this route was found to be more economical than injecting renewable methane into the grid for use in existing gas power plants because establishing a connection to the electricity grid has significantly lower costs than connecting to the gas grid. Therefore, for this assessment of costs and GHG reductions, the cost of renewable methane used in the heating and transport sectors is compared with the average cost of gas supplied through Belgium's natural gas grid. In contrast, electricity generated from renewable methane is compared with the costs and emissions from grid-average electricity in Belgium. The GHG intensities of fossil gas and grid-average electricity are given in Table 1.

The total technical production potential is compared to the estimated natural gas demand in Belgium in 2050, as well as the overall energy demand within the electricity and transport sectors projected in the 2016 EU Reference Scenario (European Commission [EC], 2016a). Estimates for heat energy demand are the sum of 2050 residential and industrial heating demand projections from Heat Roadmap Europe (Nijs, Castello, & Gonzalez, 2017).

This analysis excludes cover crops as a potential source for renewable methane production because of data gaps on the current use of cover and catch crops, also known as sequential crops, intermediate crops, green manure, winter crops, and intercrops in Belgium. Despite excluding cover crops from the primary analysis, the discussion below includes an approximate estimate of the production potential that anaerobic digestion of cover crops could contribute in Belgium in 2050, based on current trends. The same methodology used in Baldino et al. (2018b) is used in this assessment for Belgium.

Results

Figure 1 illustrates the total technical production potential and the production that could be cost-viable at varying policy incentive levels for renewable methane in Belgium in 2050, depending on end-use sector. No renewable methane production in Belgium would be cost competitive with fossil gas without policy support. At each incentive level, the quantity of cost-viable renewable methane potential increases, until the total technical production potential shown on the right-hand side of the figure is reached. Figure 1 shows that the overall technical production potential for renewable methane is approximately 900 million cubic meters for transport or heating, or approximately 1.2 billion cubic meters for electricity. The difference is due to efficiency losses incurred when upgrading and compressing raw biogas from anaerobic digestion into renewable methane that can be injected into the gas grid. The largest single source of renewable methane for either end use comes from livestock manure, which comprises around 50% of the total technical production potential in either end

Table 1: Low-carbon renewable methane feedstocks, technology pathways, and life-cycle GHG intensities.

Feedstock	Technology pathway	GHG intensity	Reference
Livestock manure	Anaerobic digestion	-264 gCO_2e/MJ (-9.45 $kgCO_2e/\ m^3$)	CARB (2015), average LCA value for dairy cows
Sewage sludge		19 gCO_2e/MJ (0.68 $kgCO_2e/\ m^3$)	CARB (2015), average
Municipal and industrial solid waste	Gasification and methanation	-26 gCO_2e/MJ (-0.93 $kgCO_2e/\ m^3$)	Wang (2017)
Crop residues		-6 gCO2e/MJ (-0.21 kgCO2e/ m^3)	Wang (2017)
Renewable power-to-gas in 2050	Electrolysis and methanation (power-to-gas)	12 gCO_2e/MJ (0.42 $kgCO_2e/\ m^3$)	Christensen & Petrenko (2017)
Belgium electricity production, grid average in 2050		67.2 gCO_2e/MJ of delivered energy	European Commission (2016), Moomaw et al. (2011)
Natural gas		72 gCO_2e/MJ (2.58 $kgCO_2e/\ m^3$)	Giuntoli, Agostini, Edwards, & Marelli (2015)

Note: CARB refers to the California Air Resources Board.

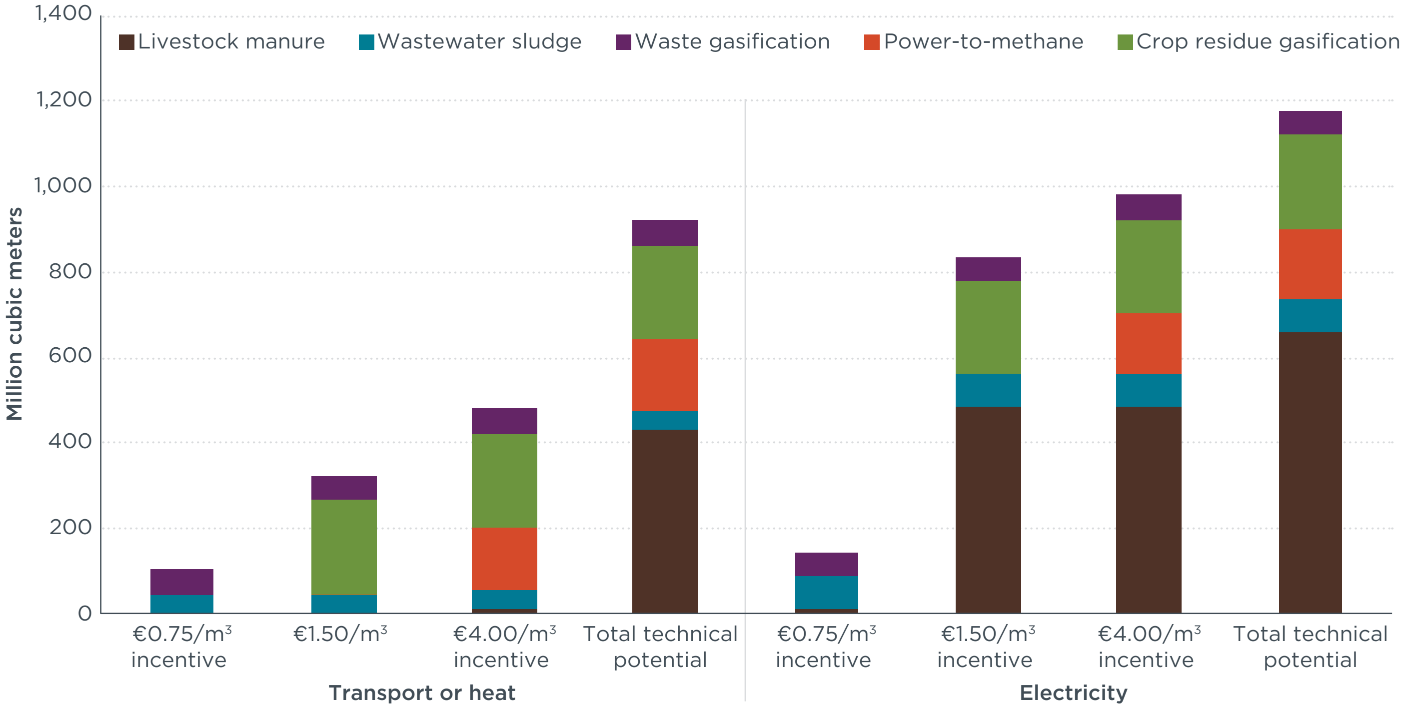

Figure 1: Total technical production potential and economically viable production potential of renewable methane delivered for transport or heating, or producing electricity, with varying levels of policy incentive (constant 2018 €) in 2050; for comparison, the current average EU natural gas price is €0.20/m³.

use. The second-largest source of renewable methane is the gasification of municipal and industrial waste and crop residues, which together account for 25%–30% of the total, depending on end-use sector. Eighty percent of the technical production potential for renewable methane from gasification is from municipal and industrial wastes, with the remainder from crop residues. This analysis assumes that the number of livestock in Belgium remains constant from the present to 2050. Any reduction in livestock numbers due to environmental, ethical, or dietary concerns would reduce the overall renewable methane production potential shown here.

Figure 1 also shows a substantial difference in the amount of renewable methane that can be cost effectively produced for electricity generation and the amount that can be injected into the grid for use in heating and transportation at each policy incentive level. Notably, at the €1.50/m³ subsidy level, which is roughly equivalent to a transport fuel subsidy of €1.50 per liter, the amount of renewable methane available to generate electricity is roughly 2.5 times the quantity of renewable methane that the same subsidy level could incentivize for injection into the natural gas grid. The cost of supplying renewable methane to the transport and heating sectors is generally higher than for electricity production. Delivering renewable methane from livestock manure to the gas grid can be cost-prohibitive because of the expense of developing pipeline infrastructure to connect dispersed dairy farms to the natural gas grid. This route is only cost-viable for the largest farms. In contrast, on-site combustion for electricity is cheaper because it not only eliminates the need for new pipeline interconnections, but also removes the requirement for on-site upgrading and compression of raw biogas into renewable methane for grid injection.

This analysis shows the cheapest sources of renewable methane are likely to be the gasification of wastes and residues along with the anaerobic digestion of wastewater sludge. Both sewage sludge and gasification yield renewable methane that is cost-viable at incentives less than €0.75/m³; however, both of these sources are severely constrained by feedstock availability. For example, whereas renewable gas production from the anaerobic digestion of sewage sludge is the cheapest source of renewable methane in this analysis, only about 48 million cubic meters per year would be available in 2050. Although gasification of municipal and industrial wastes is among the cheapest source of renewable methane, Searle and Malins (2015) estimate that only 330,000 tonnes would be available, yielding just 55 million cubic meters of renewable methane per year. The gasification of crop residues, which is slightly more expensive, would draw on a larger pool of feedstock, having a potential of more than 220 million cubic meters by 2050.

The total technical production potential for power-to-gas in Belgium is only 166 million cubic meters in 2050, suggesting that availability remains low even at high subsidy levels exceeding €4.00/m³. Power-to-gas contributes only approximately 15% to Belgium's total technical renewable methane production potential. Although overall renewable electricity deployment in Belgium is projected to increase toward 2050, the commercialization of renewable power-to-gas production is expected to face even greater barriers. In this analysis, power-to-gas production is constrained by both production cost and by facility deployment rate, assuming limited investment capital would be available for the industry in any particular year. Costs of power-to-gas production are modeled using both onshore wind and solar electricity, and also compared with the costs of connecting power-to-gas facilities directly to off-grid renewable electricity generators versus importing renewable electricity via the grid. The lowest production costs and the greatest potential production volumes in 2050 were found to be a scenario where power-to-gas facilities import solar electricity via the grid. The results shown in Figure 1 and Figure 2 represent this scenario. The potential for power-to-gas using offshore wind was not investigated. It is possible this option could have greater long-term technical production potential than grid-connected solar electricity in the Netherlands.

The specific production potential of renewable hydrogen production in Belgium is another possibility not analyzed for this study. Hydrogen is produced as an intermediate product in the power-to-gas process and producing hydrogen instead of methane can reduce costs and yield losses. hydrogen. Producing renewable hydrogen instead of methane in Belgium at an estimated annual rate of 166 million cubic meters in 2050—corresponding to 0.18 million tonnes of oil equivalent (MTOE) and 216 million cubic meters methane equivalent—would increase the total estimate of renewable gas production potential slightly, but not significantly.

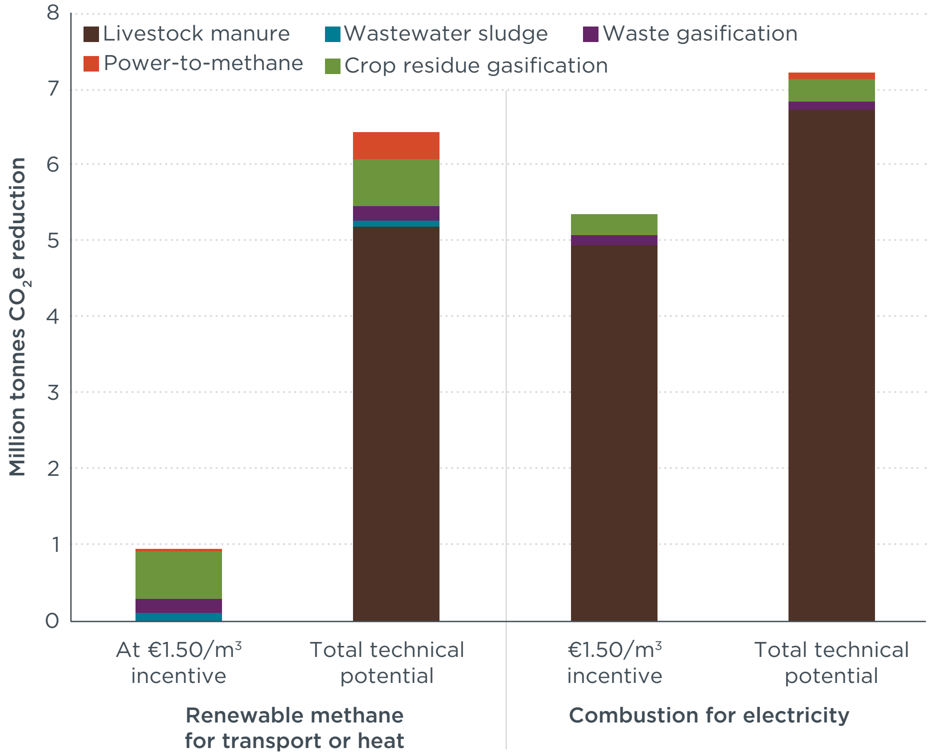

Figure 2: Greenhouse gas mitigation potential of renewable methane for transport or heating, or electricity generation in 2050 at an incentive level of €1.50/m³.

As a point of comparison, the incentive levels that this analysis estimates are necessary for most renewable methane to become cost-viable are higher than existing incentives available in Belgium. In Belgium, biogas is eligible for regional green certificates for production in Wallonia and Flanders (Elia, n.d.). In Flanders, green certificates granted toward facilities producing electricity and heat from the anaerobic digestion of livestock manure are granted a credit of €110/MWh of delivered energy, or approximately €0.33/m³ of renewable methane after accounting for typical combustion efficiency. Green certificates for biogas production in Wallonia are valued at approximately half that price, €65/MWh of delivered energy or €0.20/m³ of renewable methane (Elia, n.d.). In contrast, an incentive of €1.50/m³ would be necessary to bring most of Belgium's renewable methane production potential to market in electricity production, and even €4.00/m³ could only make around half of Belgium's renewable methane production potential cost-viable for use in the transport sector.

Figure 2 illustrates the quantity of GHG reductions that can be achieved through the deployment of additional renewable methane in Belgium by 2050 at either the €1.50/m³ incentive level or at the full technical production potential. On the left-hand side, the figure shows the GHG reductions achieved from displacing natural gas used in transportation or heating, whereas the right-hand side illustrates the GHG reductions from displacing grid-average electricity in the power sector. As with the total technical production potential estimates previously discussed, there is greater opportunity for carbon reductions through the use of renewable methane for electricity generation than in the transport or heating sectors, especially when considering the difference in cost.

Figure 2 also illustrates the contribution of different feedstocks to the total GHG reductions achievable from renewable methane in Belgium. The bulk of the GHG reductions achievable in either sector comes from livestock manure, which is not only abundant but has an extremely low carbon intensity. The low carbon intensity is realized by avoiding release of methane that would otherwise be released to the atmosphere from untreated manure (see Table 1).

Even at its total technical production potential, the amount of renewable methane that could be produced in Belgium from sustainably available feedstocks would displace only a relatively small share of the country's energy needs. Figure 3 contextualizes the 2050 technical production potential of renewable methane in Belgium, comparing it with the projected natural gas demand that year. The overall technical production potential for renewable methane in Belgium falls far short of meeting projected 2050 gas demand in the EU Reference Scenario Roadmap, with a maximum production potential of only about 5.3% penetration. The figure also illustrates the potential contribution of renewable methane relative to the projected total energy demand in the transportation, heating, and electricity sectors in 2050. If diverted to only one end-use sector, it would provide a maximum of 7.3% of transportation energy demand, 3.8% of heat demand, or 4.4% of electricity demand. Energy demands for total gas and transport are shown in terms of pre-combusted fuel and in terms of post-combustion delivered energy for the heat and electricity sectors. Factoring in costs, however, even with a fairly high incentive level of €1.50/m³, the volumes of renewable methane available to transportation and heating would plummet significantly—to only around 1% of each sector's demand. For the electricity sector, there would be a much smaller drop-off in cost-viable contributions to the total demand, as the bulk of renewable methane production potential would be available at that subsidy level.

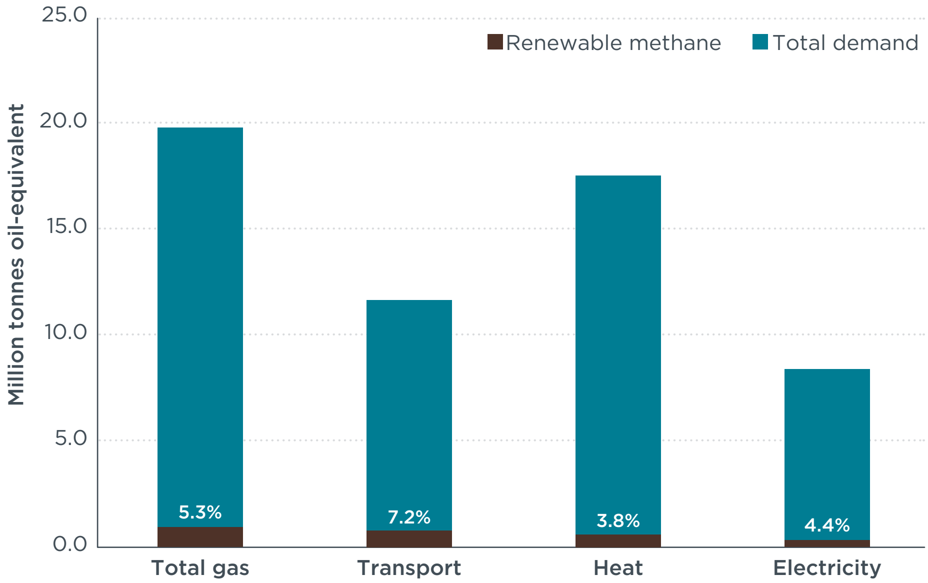

Figure 3: Maximum potential for sustainable renewable methane to displace total gas demand or total energy demand for transport, heating, or electricity generation in 2050.

Note: Total gas demand and transport shown as pre-combustion energy; heating and electricity generation shown as post-combustion energy.

Another potential source of biomass for renewable methane production is cover cropping. Although cover cropping is relatively uncommon, some have speculated that in the future cover crops may provide a low-risk feedstock for anaerobic digestion if grown on existing farmland in between crop rotations. Based on the assumptions outlined in Baldino et al. (2018b), an estimated maximum of 9 million cubic feet of renewable methane per year could be available from cover cropping in 2050, which would not significantly change the estimate provided in this report of the total volume of renewable methane production potential.

Comparison to literature

Belgium has established ambitious climate targets as part of its Paris Agreement commitments, but there has been relatively little analysis of the changes necessary to its natural gas market to meet those goals. FTI Consulting (2018) evaluates the role of renewable gas, primarily from power-to-gas, for meeting Belgium's long-term climate goals. The authors draw upon a 2018 study from Ecofys, estimating that there is 1 million MTOE of renewable methane production potential from the anaerobic digestion and gasification of sustainable biomass in Belgium (Van Melle et al., 2018). That result is very close to this report's estimate of the renewable methane production potential from biomass, which amounts to 0.91 MTOE. Baldino et al. (2018) provides a more detailed comparison of this study's methodology at the EU-28 level to that developed by Van Melle et al. (2018).

FTI Consulting (2018) also assesses the production potential for power-to-gas, estimating that approximately 2 MTOE of renewable gas would be available by 2050, meeting 10% of Belgium's energy demand. In contrast, the analysis underlying this report finds that the total technical production potential of power-to-gas would only amount to roughly 0.15 MTOE of renewable methane, an order of magnitude lower. Furthermore, that total would be available only at the highest incentive levels of €4.00/m^3 and higher, likely putting it out of reach in most cases. The primary factors contributing to the higher availability of power-to-gas in FTI's analysis are its assumptions about capital costs, renewable electricity prices, and technology deployment rates, informed by Thomas, Mertens, Meeus, Van der Laak, and Francois (2016). Thomas et al. (2016) extrapolates from today's hydrogen prices based on steam methane reforming from fossil fuels, estimating that by 2050 hydrogen produced from electrolysis would be cost-competitive; furthermore, the authors estimate that in 2015, hydrogen production has the same levelized cost as existing biogas feed-in tariffs. On the contrary, however, the anlysis upon which this study is based assesses the production potential of power-to-methane that can be used in natural gas infrastructure and vehicles without blending constraints, and the conversion step from hydrogen to methane raises production costs somewhat. It also finds that power-to-methane production potential is constrained by high renewable electricity prices, driving its cost far above that for conventional steam methane reforming (Christensen & Petrenko, 2017).

Conclusion

This analysis finds that the total production potential of renewable methane in Belgium is relatively limited and would only meet roughly 5% of Belgium's projected 2050 natural gas demand. At this maximum production level, renewable methane could displace existing fossil fuel consumption and reduce emissions by roughly 6.5 to 7 million metric tonnes of CO_2e, depending on end-use.

A cost analysis demonstrates that it is much more cost-effective to use most renewable methane production potential for on-site electricity generation rather than injecting it into the natural gas grid. Because roughly 50% of Belgium's sustainably available renewable methane production potential comes from livestock manure, the estimated cost of grid interconnections for distant farms would make grid injection cost-prohibitive in the absence of extremely high policy incentives. Gasification of wastes and residues is a promising source of renewable methane for either grid injection or electricity generation, with the bulk of the production potential available at incentive levels of €0.75/m^3 or lower. Together these resources comprise 30%–35% of Belgium's renewable methane production potential. The expectation is that renewable power-to-methane production potential will be limited in Belgium except at the highest levels of policy support, even in 2050.

Overall, the renewable methane that could be produced in Belgium would make only a modest contribution to Belgium's overall Paris Agreement ambitions and long-term plan to achieve carbon neutrality. Although incentives should be made available to those renewable methane producers using sustainably available feedstocks with good GHG performance, most of the renewable methane potential production in Belgium is not particularly cost-effective to deploy.

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