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BRIEFING

OCTOBER 2018

What is the role for renewable methane in European decarbonization?

THE GROWING FOCUS ON RENEWABLE METHANE

European Union governments and stakeholders are increasingly focusing on renewable methane as a key strategy for achieving climate goals. Methane is often seen as a decarbonization solution for the transport sector. Renewable methane from waste is eligible for a 3.5% subtarget for advanced biofuel consumption in the recast Renewable Energy Directive for 2030 (RED II)[1] and is strongly supported by Italy's "Biomethane Decree."[2] But some stakeholders also see a role for renewable methane in the power and heating sectors. For example, the Gas for Climate consortium of gas transport companies and renewable methane producers commissioned a report asserting that all gas demand in transport, industry, buildings, and power generation could be met with renewable methane and fossil gas with carbon capture and storage by 2050.[3]

1 Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources - Analysis of the final compromise text with a view to agreement, General Secretariat of the Council of the European Union, Interinstitutional file, June 21, 2018, http://www.consilium.europa.eu/register/en/content/out?&typ=ENTRY&i=LD&DOC_ID=ST-10308-2018-INIT.

2 Promozione dell'uso del biometano nel settore dei trasporti [Promotion of the use of biomethane in the transport sector], Ministero dello sviluppo economic, March 2, 2018, http://www.sviluppoeconomico.gov.it/index.php/it/normativa/decreti-interministeriali/2037836-decreto-interministeriale-2-marzo-2018-promozione-dell-uso-del-biometano-nel-settore-dei-trasporti.

3 Tim van Melle, Daan Peters, Jenny Cherkasky, Rik Wessels, Goher Ur Rehman Mir, & Wieke Hofsteenge, *Gas for Climate: How gas can help to achieve the Paris Agreement target in an affordable way*, (Ecofys: Utrecht, 2018), https://www.gasforclimate2050.eu/gas-for-climate.

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Renewable methane is particularly attractive in the short term because it is the only advanced, low-carbon alternative fuel pathway that can be produced using fully mature and available first-generation technology. Renewable methane from anaerobic digestion of livestock manure and sewage sludge can sometimes more than offset the avoided emissions from burning fossil fuels.[4] In the longer term, low-carbon renewable methane can be produced from a wider range of feedstocks using second-generation technologies, including gasification and power-to-methane, in which electricity and CO_2 are used to create methane.

Using manure and sewage sludge for renewable methane production is practical in the short-term, but does it make sense to invest in a broader methane strategy for the longer term? Gas distribution and consumption requires dedicated infrastructure, vehicles, and power and heat generators. Especially for transport, where gas penetration is currently low, moving to renewable methane would require large-scale investment in the vehicle fleet and fueling infrastructure. For other uses of methane, investment would be needed to maintain and potentially expand the existing gas grid. If these infrastructure and vehicle investments are made, is it realistic to expect renewable methane to decarbonize this fuel stream? This briefing summarizes a technical study: "The potential for low carbon renewable methane in heat, power, and transport in the European Union."[5] We present the total amount of renewable methane that can realistically be expected in the 2050 timeframe and discuss its competitiveness in the transport, power, and heating sectors.

ENVIRONMENTAL PERFORMANCE OF RENEWABLE METHANE

As with liquid biofuels, the GHG impacts of renewable methane range widely depending on the feedstock and conversion technology used. Generally, renewable methane generated from wastes delivers greater GHG reductions compared with methane from crops. Figure 1 shows that waste-based renewable methane pathways have much lower GHG emissions than fossil gas, which is shown in the dotted line. Silage maize is a common biogas feedstock in the EU, but its production competes for arable land with food and feed crops. This leads to indirect land use change (ILUC), increasing total GHG emissions. As another example of a potential renewable methane pathway that does not offer strong GHG savings, gasified roundwood, or logs, would have high land-use-change emissions because forest carbon stocks are depleted when trees are felled for roundwood production.

In our assessment of renewable methane potential, we include only feedstocks that offer high GHG savings compared with fossil gas. Some of these sustainable pathways still have positive GHG emissions. Renewable power-to-methane, for example, leads to emissions from constructing new wind and solar installations and from the fuel conversion process. In the 2030 timeframe, producing power-to-methane in the EU

4 "Data Dashboard: Slide 5. 2017 Volume-weighted average carbon intensity by fuel type.," California Air Resources Board, accessed September 14, 2018, https://www.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm.

5 Chelsea Baldino, Nikita Pavlenko, & Stephanie Searle, *The potential for low carbon renewable methane in heat, power, and transport in the European Union*, (ICCT: Washington, DC, forthcoming).

will most likely lead to additional emissions from indirect effects on renewable energy supply elsewhere.[6]

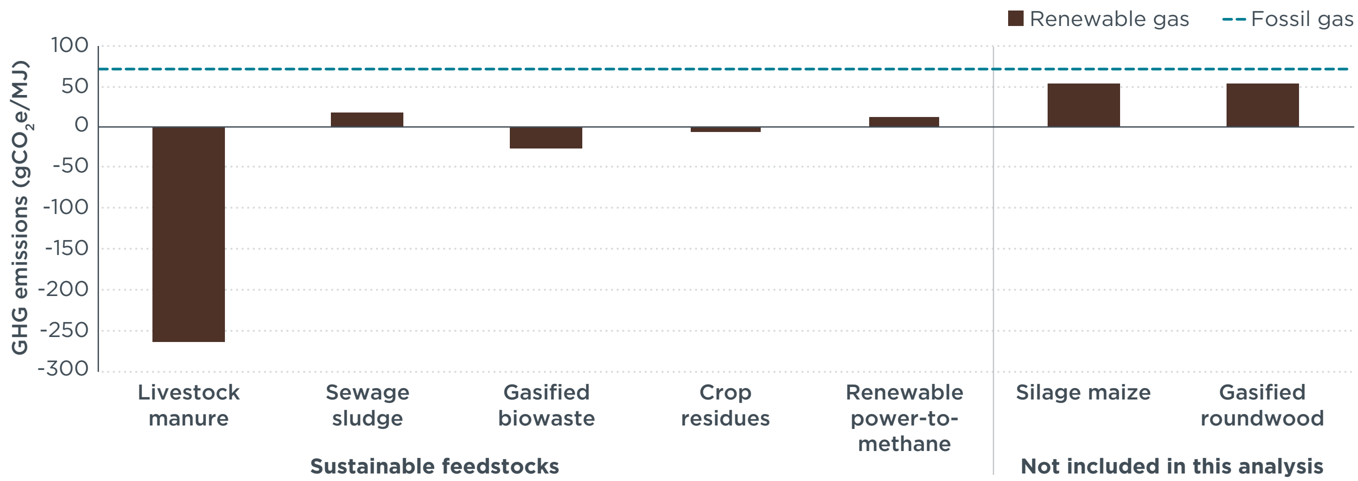

Figure 1. GHG emissions from sustainable renewable methane pathways and from unsustainable example pathways[7]

Some stakeholders, including the Gas for Climate authors, consider the potential to produce renewable methane from cover crops grown in sequence with main crops, for example growing maize as the main crop in the summer and rye as the cover crop in the winter. While there are some examples of successful cover cropping in Italy,[8] across the EU it is seldom practiced; only around 3% of cropped area uses cover crops, and this rate is increasing slowly, if at all.[9] The scarce data available suggest that cover crops are generally low-yielding, short-rotation crops such as fodder radish and yellow mustard grown to reduce erosion. They are often ploughed into the soil rather than harvested, presumably because the yields are so poor.[10] It is not clear that these conditions can support higher-yielding cover crops, especially not silage maize. The Gas for Climate study assumes silage maize would be grown as a cover crop throughout the EU, whereas in practice it is a warm-weather crop suitable for winter

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6 Stephanie Searle &, Adam Christensen, *Decarbonization potential of electrofuels in the European Union.*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/decarbonization-potential-electrofuels-eu.

7 Data sources: Stephanie Searle &, Adam Christensen, *Decarbonization potential of electrofuels in the European Union.*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/decarbonization-potential-electrofuels-eu; Hugo Valin, Daan Peters, Maarten van den Berg, Stefan Frank, Petr Havlik, Nicklas Forsell, & Carlo Hamelinck, *The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts*, (Ecofys: Utrect, 2015), https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf; Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, *Official Journal of the European Union*, L 140/16, April 23, 2009, https://eur-lex.europa. eu/legal-content/EN/ALL/?uri=celex%3A32009L0028; Stephanie Searle, Nikita Pavlenko, Sammy El Takriti, Kristine Bitnere, *Potential greenhouse gas savings from a 2030 greenhouse gas reduction target with indirect emissions accounting for the European Union*, (ICCT: Washington, DC: 2017), https://www.theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf.

8 Described in Tim van Melle, Daan Peters, Jenny Cherkasky, Rik Wessels, Goher Ur Rehman Mir, & Wieke Hofsteenge, *Gas for Climate: How gas can help to achieve the Paris Agreement target in an affordable way*, (Ecofys: Utrecht, 2018), https://www.gasforclimate2050.eu/gas-for-climate.

9 Alliance Environnement. (2017*). Evaluation study of the payment for agricultural practices beneficial for the climate and the environment*. Retrieved from https://ec.europa.eu/agriculture/sites/agriculture/files/fullrep_en.pdf

10 *Ibid.*

cover cropping only in tropical countries.[11] Cereals can be grown as a winter crop in warmer European countries, but it is not clear that cover crops are viable across all of Europe. Interviews with farmers suggest that harvest of the main crop occurs too late in the fall to plant a cover crop in much of Europe, including regions of France and Germany. Farmers are further reluctant to plant cover crops because of problems with weeds in establishing the next crop and disease transmission among cereals.[12] It is important to remember that if cover crops already being grown for food and fodder are diverted to renewable methane production, this will impact food and feed markets and cause ILUC. Lastly, cover crop production would have relatively high cultivation emissions for the small amount of biomass produced per hectare, limiting the GHG savings of this pathway. Because it is not clear that there is significant potential for additional biomass production with cover cropping in the EU, we do not include this feedstock category in our main analysis, but we do provide an illustrative estimate of the potential from this pathway below.

There is one factor that adds considerable uncertainty to the GHG performance of all renewable methane pathways: methane leakage. Because methane has a much stronger climate-warming impact per molecule than carbon dioxide (CO_2), a small amount of leakage from a renewable methane supply chain could significantly reduce the overall GHG savings of the pathway. Very little data has been collected on methane leakage from anaerobic digestion systems, while probably none has been collected from gasification and power-to-methane projects. The small amount of available data and modeling studies suggest the methane leakage rate for anaerobic digestion and gas compression generally ranges from less than 1% up to around 2% but can be much higher with improper facility operation. This is similar to estimates of methane leakage from fossil gas supply chains, and is included in the calculations of lifecycle GHG emissions for some of the renewable methane pathways in our assessment (those for which data is available).

There is some evidence that additional leakage of 1%–3% occurs when combusting gas, both renewable and fossil, in vehicles and in heat and power generators. This is not included in our lifecycle GHG emissions estimates. Leakage could substantially reduce the climate benefits of even the more sustainable renewable methane pathways. For example, a leakage rate of 5% would reduce the GHG savings of methane from a typical small sewage sludge digester from 75% to 40%. With a leakage rate of 11%, this pathway would not have any GHG savings over fossil gas. However, we caution against drawing any conclusions on the climate impact of leakage on renewable methane pathways because the data on leakage rates is scarce and highly uncertain.

ECONOMICS OF RENEWABLE METHANE PRODUCTION AND CONSUMPTION

Poor economics limit the production of many types of renewable methane today, and that constraint is likely to persist into the future because it is difficult for renewable methane production to compete with inexpensive fossil gas. In our technical study, we

11 For example, winter corn is planted in Mexico: “Mexico: Winter Corn Production (Irrigated),” U.S. Department of Agriculture, accessed September 24, 2018, https://www.usda.gov/oce/weather/pubs/Other/MWCACP/Graphs/Mexico/MexWinterCornProd_0509.pdf

12 “Evaluation study of the payment for agricultural practices beneficial for the climate and the environment,” Alliance Environnement *(2017),* https://ec.europa.eu/agriculture/sites/agriculture/files/fullrep_en.pdf.

assess the economics of producing various renewable methane pathways in transport, heating, and power. Our economic analysis, data sources, and assumptions are described in our technical paper[13] and in an earlier study.[14]

We find that all renewable methane pathways would require public incentives to expand production. Figure 2 shows the potential for using renewable methane in transport, heating, or power at various incentive levels as well as the maximum technical potential. These potentials are not additive across sectors. The renewable methane potential in transport and heating is the same in our analysis because we assume that this methane must be delivered to the gas grid for either end use: Transport fueling stations and homes as well as district heating systems are typically connected to the distribution gas grid. While many gas power generators are similarly connected to the gas grid, renewable methane can also be combusted on-site at farms without any grid connection.

We find that one of the most economical renewable methane pathways uses wastewater sludge, the solids removed from wastewater treatment ponds. Sludge from wastewater treatment can be processed inexpensively by anaerobic digestion; is concentrated in large quantities, allowing economies of scale; and generally is processed relatively close to population centers, allowing ready connection to the urban gas grid. For these reasons, a large proportion of wastewater sludge potential in the EU is already utilized for renewable methane production, largely for on-site heating and power generation.

Gasification of waste and sustainably available biomass residues also have high potential in the 2050 timeframe with moderate policy incentives, although there is some uncertainty in the economics of this pathway. As an emerging second-generation technology, gasification for methane or liquid fuel production has been demonstrated only on a small scale; no large-scale commercial facilities have been built. Our finding that gasification can be economical with moderate policy incentives once commercialized is thus somewhat theoretical. In addition, new industries take time to ramp up, and we expect that the rate of facility deployment will constrain the potential for renewable methane from this pathway in some countries in the 2050 timeframe. In most countries, we expect feedstock availability to limit production. Similarly, power-to-methane is an emerging technology with uncertain potential. We expect cost and the rate of facility deployment to be the main limiting factors for power-to-methane.

13 Chelsea Baldino, Nikita Pavlenko, & Stephanie Searle, *The potential for low-carbon renewable methane in heat, power, and transport in the European Union*, (ICCT: Washington, DC, forthcoming).

14 Chelsea Baldino, Nikita Pavlenko, & Stephanie Searle, *The potential for low-carbon renewable methane as a transport fuel in France, Italy, and Spain*. (ICCT: Washington, DC, forthcoming).

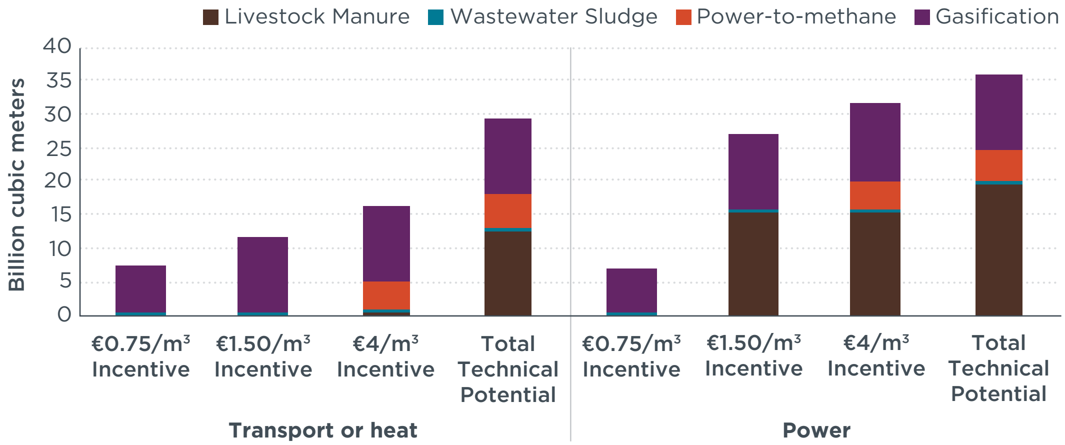

Figure 2. Total technical potential and economically viable potential of renewable methane delivered to transport or heat or power with varying levels of policy incentive in 2050 (constant 2018 €); for comparison, the current average EU wholesale natural gas price is €0.2/m^3.

While the greatest potential for any feedstock in our analysis lies with livestock manure, there are significant obstacles to unlocking it. Unlike the other pathways, using livestock manure for renewable methane production must occur far from population centers and also typically far from gas pipelines. Manure is difficult to transport and is generally processed on-site at farms. The gas produced from manure can be combusted in an on-site boiler, delivering power for farm operations with only modest policy support. Excess power can be exported on the power grid. But delivering manure gas to gas pipelines is far more difficult. The gas must be cleaned and compressed on-site, requiring participating farms to build and operate facilities, and transported to the nearest gas pipeline either by truck or by building a pipeline extension. Both options are expensive and greatly limit the potential for delivering manure gas to the gas grid.

We estimate that policy incentives equivalent to €1.50/m^3 would be necessary to support a significant amount of renewable methane production using sustainable feedstocks, as shown in Figure 2. To enable the economical use of most of the potential renewable methane resources in electricity, €4/m^3 would be necessary. Even this amount would achieve only around half the total renewable methane potential for transport or heating. Compared with the current average EU wholesale gas price of €0.20/m^3, this represents a high level of policy support. Translated, €4/m^3 corresponds to €1.13/kWh of policy support, also high compared with current wholesale electricity prices ranging from €0.02–€0.11/kWh in EU states.[15] For transport, policy support of €1.50–€4/m^3 would be roughly equivalent to subsidies of €1.50–€4/L of diesel equivalent, or a carbon price of €580–€1,350 per tonne of CO_2 equivalent (CO_2e) abated. If renewable methane were used as a strategy to meet vehicle CO_2 standards, it would cost €90–€230 per gCO_2e saved per kilometer over the lifetime of a vehicle. This cost is similar to or exceeds the €95 penalty for not complying with the proposed

15 Current wholesale electricity prices from: *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Energy prices and costs in Europe*. European Commission, *COM(2016) 769 final*. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_769.en_.pdf.

2030 standards and thus is unlikely to represent a cost-effective strategy for meeting the standards.[16]

It is important to note that some of these renewable methane feedstocks can also be used for liquid fuel production. Gasified biomass can be processed by Fischer Tropsch synthesis, producing drop-in diesel and jet fuel that can be blended at high rates in conventional liquid fuels and used in existing vehicles and infrastructure instead of methane. Renewable power can similarly be used to produce power-to-liquids instead of power-to-methane. In another study, we find greater potential for power-to-liquids than power-to-methane because power-to-liquids is more competitive with diesel fuel than power-to-methane is with relatively inexpensive fossil gas.[17] Competition from liquid fuels production could raise feedstock costs above what we have assumed in the present study and could reduce the overall renewable methane potential. In any case, it is clear that renewable methane production faces economic headwinds, especially for use in transport and heating.

OVERALL POTENTIAL FOR DECARBONIZATION OF TRANSPORT, POWER, AND HEATING USING RENEWABLE METHANE

Sustainable renewable methane can achieve significant GHG mitigation, but the overall potential for decarbonization from renewable methane is limited. Even if cost barriers can be overcome, we find that the maximum renewable methane potential from the feedstocks explored here is far lower than the projected total gas demand in the EU in 2050 (Figure 3). Disregarding cost limitations, renewable methane could displace at most 36 billion m^3, or 7% of current gas demand and 12% of projected gas demand in 2050. If the entire renewable methane potential were used in transport, it could displace only 7% of total transport energy demand in 2050. If it were instead used in heating, it could displace 10% of energy use in residential heating, or 3% of energy demand in power generation.[18]

16 Proposal for a Regulation of the EP and of the Council setting emission performance standards for new passenger cars and for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles and amending Regulation (EC) No 715/2007 (recast), European Commission COM/2017/676, November 8, 2017, https://eur-lex.europa.eu/resource.html?uri=cellar:609fc0d1-04ee-11e8-b8f5-01aa75ed71a1.0001.02/DOC_1&format=PDF.

17 Stephanie Searle, Adam Christensen, *Decarbonization potential of electrofuels in the European Union*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/decarbonization-potential-electrofuels-eu.

18 Energy demand estimates for 2050 from: European Commission, "EU Reference Scenario 2016: Energy, transport and GHG emissions, Trends to 2050" (2016), https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf.

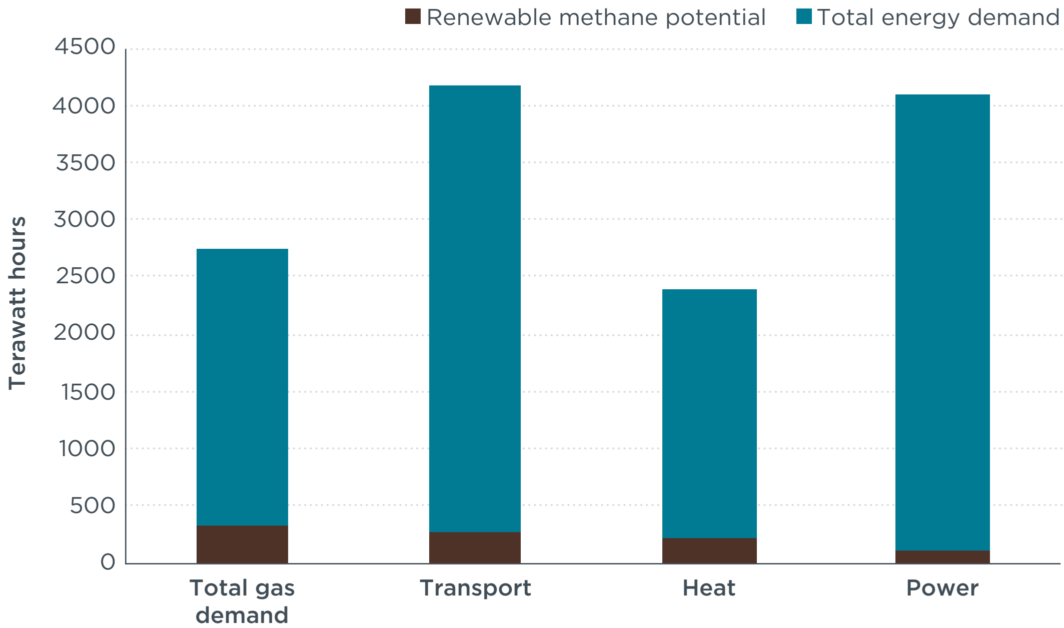

Figure 3. Maximum potential for sustainable renewable methane to displace total gas demand, or transport energy demand, or energy demand for heating, or energy demand for power

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

This result is far less optimistic than the conclusions of the Gas for Climate study commissioned by gas transport companies and renewable gas producers. That study estimated a total renewable gas potential of 122 billion m^3 (including 24 billion m^3 of hydrogen), more than three times greater than the maximum potential identified in our analysis. One-third of the potential in the Gas for Climate study comes from cover cropping. Based on the challenges to cover cropping, we think this source is unlikely to deliver the volumes assumed in the Gas for Climate study. Although we did not include cover crops in our main analysis, based on current trends in cover cropping we estimate that this pathway could add at most 1.4 billion m^3 of renewable methane per year in 2050, adding only 4% to our calculated technical renewable methane potential. Another difference is in gasification efficiency. Our assumption for future gasification yields are taken from a 2015 study[19] written by some of the same authors (Ecofys) as produced the Gas for Climate study. In Gas for Climate, Ecofys assumes gasification yields 3.5 times higher and costs three times lower than in their previous study, without clear justification. A third difference is that Ecofys assumed that renewable power would be used to produce hydrogen, a more efficient pathway than power-to-methane. Had we made the same assumption, we would have estimated a technical maximum of 6 billion m^3 for hydrogen, increasing our total technical potential for renewable gas by 4%.[20] Other key differences are that our analysis accounts for limitations on anaerobic digestion capacity because of losses in gas conditioning and compression as well as limitations on gasification and power-to-methane facility deployment rates. Our results for renewable methane potential for France are also much lower than the findings in

19 Daan Peters, Sacha Alberici, & Jeff Passmore, *How to advance cellulosic biofuels*, (Ecofys: Utrecht, 2016), https://www.theicct.org/sites/default/files/publications/Ecofys-Passmore%20Group_How-to-advance-cellulosic-biofuels_Dec2015.pdf.

20 Assuming a hydrogen-methane conversion efficiency of 77%. References are provided in Stephanie Searle &, Adam Christensen, *Decarbonization potential of electrofuels in the European Union*, (ICCT: Washington, DC, 2018), https://www.theicct.org/publications/decarbonization-potential-electrofuels-eu.

a study commissioned by ADEME, the French Environment and Energy Management Study.[21] Similarly to the Gas for Climate study, the ADEME study includes optimistic assumptions for technology costs, deployment rate for emerging technologies, and high biomass potential from cover crops.[22]

Our study finds that sustainable renewable methane can play a small role in decarbonizing the EU economy in 2050, though it cannot represent the primary strategy for decarbonizing an entire sector. Given that this resource is limited, should it be used for heating, power, or transport? For livestock manure gas, the answer is clear: This resource should be used for power generation on-site at farms. Sewage sludge is largely already used for power generation as well. In the longer term, gasification could be competitive in both transport and power generation. If used for power, it would be more efficient and cost-effective to combust the raw syngas rather than converting it to methane, and it would not use existing gas infrastructure.

Using power-to-methane for power generation seems counterintuitive, and our work confirms there are related issues. The power-to-methane process involves converting power to a gaseous fuel and then combusting it to generate power again. The overall process incurs high conversion losses, meaning it makes more sense to use the original renewable power directly rather than convert it to a gaseous fuel. There is an argument that power-to-methane and power-to-liquids can be energy storage solutions as the EU power mix transitions to a higher share of variable wind and solar,[23] but more cost-effective solutions to this problem may arise. For example, variability in wind and solar power generation can be offset by transmitting renewable power across a larger grid area,[24] and the EU is already working to improve cross-border power transmission for that reason.[25] In addition, battery storage and electric vehicles are also likely to play a role as flexible electric loads to manage renewable electricity loads in the future. Generating heat directly from renewable power would also be more efficient than using power-to-methane.

In the transport sector, power-to-liquids has several advantages over power-to-methane. It is more price-competitive with fossil fuels; it can be used in aviation, which has few alternatives to liquid fuels; and it can be delivered directly to existing vehicles. If power-to-methane is injected into the gas grid, the vast majority of it will be used in heating and power generation rather than transport. Delivering renewable methane directly to vehicle fueling stations by truck would add cost and render power-to-methane even more uncompetitive. Based on our assessment, there is not a clear justification for using power-to-methane in any sector.

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21 ADEME, "Gas independence in France in 2050: A 100% renewable methane mix in 2020? Study summary." (January 2018), https://www.ademe.fr/sites/default/files/assets/documents/renewable-gas-mix-2050-010521.pdf

22 A fuller comparison with the ADEME study is given provided in: Chelsea Baldino, Nikita Pavlenko, & Stephanie Searle. (2018b). *The potential for low-carbon renewable methane as a transport fuel in France, Italy, and Spain*. (ICCT: Washington, DC, 2018), Link forthcoming.

23 Discussed in: SAPEA, "Novel carbon capture and utilisation technologies" (2018), https://www.sapea.info/wp-content/uploads/CCU-report-May2018-3.pdf.

24 Matthias Fripp. "Greenhouse gas emissions from operating reserves used to backup large-scale wind power." *Environmental Science & Technology* 45, no. 21, (2011): 9405-9412.

25 "Electricity interconnection targets," European Commission, accessed September 14, 2018, https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest/electricity-interconnection-targets

We offer four more specific policy recommendations:

1. **Use livestock manure gas for on-site power generation.** This pathway is cost-effective with moderate incentive value and could deliver nearly 200 million tonnes of CO_2e reduction. Our analysis finds this to be the largest climate mitigation opportunity of any renewable methane pathway assessed here. Although it may play smaller roles filling particular nearer-term niches while zero-emission transport alternatives emerge, gas is not a viable long-term decarbonization strategy for transport.

2. **Do not prioritize renewable methane fuels over renewable drop-in liquid fuels for transport.** Power-to-liquids and drop-in liquid fuels produced from gasification may be more economical and have a greater potential market share than gaseous fuels. Based on best available research to date, there is no climate or other benefit in prioritizing gaseous over liquid fuels. However, we do believe that incentives for low-carbon advanced fuels should be available equally to liquid and gaseous forms to enable innovative solutions for the most economic low carbon fuel pathways.

3. **Require all renewable methane producers to meet minimum standards for preventing methane leaks.** Leaks into the atmosphere could make a low-carbon fuel more damaging than fossil fuels. There not yet adequate regulations to ensure a tighter upstream gas supply chain. More data on methane leakage is urgently needed to confirm whether any renewable methane pathways achieve their theoretical climate mitigation benefits.

4. **Support other decarbonization strategies in transport, power, and heating.** Renewable methane can decarbonize only a very small fraction of the energy needs in these sectors. Many alternatives, such as wind and solar power, heat pumps, and battery- and hydrogen-electric vehicles all appear to be more economical, more reliably capable of climate benefits in the near term, and more central for long-term decarbonization in the EU.