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Short communication

Biomass to hydrogen: A short biomass potential availability and conversion survey for Dutch municipalities

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Abstract

The local availability of lignocellulosic biomass was estimated for an arbitrary but representative Dutch municipality to facilitate the conversion and use of hydrogen on a decentralized scale. This study reveals that there is a large potential for this biomass at many locations to play important roles in the energy transition. It is meant as a call to the scientific community to activate individuals and get some inspiration.

Introduction

Many Dutch municipalities have the ambition to become a frontrunner in the energy transition. They are mostly countryside municipalities that have some regional prominent economic characteristics which are threefold 1) a large amount of agriculture, 2) quite some companies rooted in the agricultural sector and 3) a good infrastructure. The first two points are condensed into a single term ‘the agro-food sector’.

Additionally, for many Dutch municipalities the challenge is to increase their innovativeness, sustainability, and knowledge and to enforce in this way their economic potential.

Therefore, I asked myself the question of what the potential availability of biomass in such communities is and how it can be used in the energy sector. In the process from the energy source to usage, some conversions are required. As an intermediate energy carrier, I immediately identified hydrogen, H_2, as a means. But of course, direct combustion of biomass is possible. I used hydrogen as an intermediate because of its overall recognized abilities which lead to a standard and the associated technology found a breakthrough a couple of years ago by many stakeholders which lead to increasing price reductions of its required infrastructure. The process keeps on going and this momentum should be used although it is of course not the best choice for any application.

Additionally, the study emphasizes that it is important to take action in the right direction, the best direction is just an unimportant luxury.

Of course, such a study can provide valuable insights and information for a variety of stakeholders, including government officials, entrepreneurs and members of the general public. It can serve as a starting point for further research and can help inform policy and decision-making related to the use of lignocellulosic biomass for hydrogen production on a decentralized scale. The study will likely include several conclusions, strategy suggestions, and recommendations that can guide future efforts in this area. Additionally, it will identify areas where more research is needed to fully understand the potential of this technology and how it can be best utilized to support a sustainable energy transition.

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Small-scale integrated (synthesis and application) systems are important if not crucial because of their advantages being fourfold

1) Independence,

2) Available technology at sufficiently high TRL,

3) Affordable systems by local entrepreneurs at a limited scale and

4) Facilitating demo applications is therefore relatively easily accessible as well, important for proof of concepts.

To my opinion, it is both required and challenging to initiate a movement towards a more sustainable energy transition fast, for people feeling a sort of responsibility and don't want to leave it to (rather slow) governments. Individuals, small groups, and entrepreneurs can play an important role in getting the process started. By building their own decentralized hydrogen production and usage systems and joining efforts, they can serve as "opinion leaders" and pave the way for wider adoption. The key is to find a few people who are passionate about the cause and are willing to take the first steps, which can be difficult. But once the movement starts to grow, it will become easier to attract more people and resources to the cause and to facilitate the transition to a more sustainable energy future.

This document is meant to serve as a kind of convincing manual to provide several important and facilitating partners, like municipalities for an efficient process for obtaining government permits or licenses for a specific project or activity. This can include streamlined and/or simplified paperwork, reduced wait times for approvals and reduced regulatory burdens. Governments may implement quick licensing procedures to encourage investment, stimulate economic growth, and make it easier for businesses and individuals to undertake projects that align with public policy goals, such as clean energy development. Of course, a similar survey may be conducted to adjust it to specific situations.

Method

It is very difficult to investigate the availability potential of an area covered by multiple applications of it. Common land applications include residential, commercial, industrial, agricultural, and natural/conservation areas. The latter two are the main inputs for biomass whereas the first two might add in waste streams. Each type of land use may have different regulations, zoning requirements and potential impacts on the environment and local communities. Understanding the division of land applications can help plan for sustainable land use and development, and balance competing land use demands. However, it is quite impracticable to investigate potential biomass sources by their very local use and integrate it. This could be executed by detailed interviewing of notably agricultural businesses. A gross estimation would be more helpful.

Therefore, a literature search was performed to find a reference case. This case was then mapped, to obtain an order-of-magnitude estimation, for the case considered. The study will also examine the potential applications of this technology, such as its use in residential, commercial, or industrial settings.

Biomass availability

The investigation started by taking a representative arbitrary (but very useful, though as it is the place of my residence) Dutch countryside municipality, which was Land van Cuijk, further abbreviated as LvC. LvC is inhabited by about 90.000 individuals and has a surface of 351 km^2. I found a trustworthy 2011 study of Oak Ridge National Laboratories (USA), invoking 50 scientific experts and 11 scientific reviewers, commissioned by the USA Department of Energy (DOE) [1]. Although from a totally different region, I found it adequate for use as a reference. In [1] we observe that a local yearly amount of biomass production can amount up to 5500 dry tons per annum and per square mile in the United States, Figure 1. It was based on a conservational estimation of available resources of cellulosic feedstocks including forest and agricultural biomass, as well as specific energy crops. The limit of $ 60 per dry ton is a realistic market price limit and can compete with other energy carriers. Other assumptions are realistic, including sustainability, and do not have any severe impact. To my opinion, LvC can compete with this amount as agricultural intensity, soil fertility, and efficiency can be assumed at least as large. Therefore, I would estimate LvC's annual biomass production at 2000 dry tons per annum per square km. A regional surface of 351 km means a yearly availability of 700000 tons. For confirmation, I contacted the current principal investigator, of this project [2]. He referred me to the updated report [3] in which it was confirmed that nothing changed severely. Because this is just an order-of-magnitude survey I kept the 2011 numbers.

Conversion to hydrogen

In a recent review on biomass conversion to hydrogen, [4], it is concluded that the best H_2 yield from biomass is through (thermochemical) gasification. The general air gasification reaction of biomass is presented in Equation (1),

$$Biomass+Air \rightarrow N_2+CO+H_2+Co_2+CH_4+H_2O+LHC+Tar+char \quad (1)$$

In which LHC denotes light hydrocarbons. We can easily convert many species on the right-hand side by thermochemical means, separate or safely emit, filter them out, or use them. It can be taken care of by internally integrated means or by after-treatment.

From local estimated yearly feedstock and table 4 of [2] (H_2 Yield of ~ 100 (g/kg feedstock)) we can conclude the potential possibility to produce 70-10^6 kg of H_2 each year. With a hydrogen energy density of 120 MJ/kg, we obtain 8.4 PJ/yr at a conversion efficiency of 100%. A value of 30% would be a quite conventional lower estimate. With this, we come up to 2.5 PJ/yr and we can provide feedstock for the electricity consumption of 250000 households[1].

[1]According to CBS the mean Dutch domestic annual electricity consumption in 2021 was 2810 kWh = 10 GJ [6].

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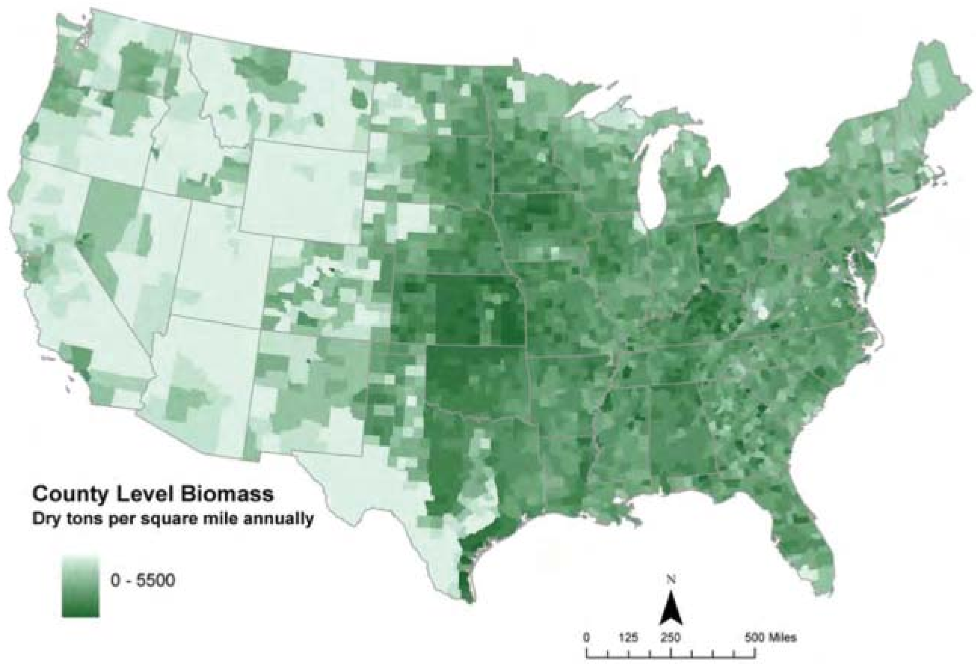

Figure 1: Potential county-level resources at $60[2] per dry ton or less in 2030, under baseline assumptions specified in [1]. More recent and detailed data became available in [5].
[2]All costs to farmgate or roadside (excludes handling and loading, transportation and storage).

This would be equivalent to about 700 GWh altogether usable potential even in the case of partial use/ decentralizing feedstock harvest, conversion, and application efficiency. For the total household energy supply (including gas) the ratio is about 3 to 1, for gas use and electricity respectively. So, for the total energy use, we would need 4 times as much as the amount above, reducing the number of households to 62000, still more than we probably host in our region! Indeed, with about 100000 people let us assume a clustering of 3 people per household the region's household energy need can be covered almost two times. If local industry needs are equivalent to total household needs we can possibly cover the entire region in total energy demand.

In the following points, we concentrate on the best H_2 yield from biomass through (thermochemical) gasification. Thermochemical conversion has the advantage of being available at a large production scale because the technologies used are based on current well-established methods for converting fossil fuels. Therefore, the industrial application has already been established. Gasification and pyrolysis implementation methods are already designed for a wide variety of dried feedstocks, while steam gasification and steam reforming are the best compromises for wet biomass treatment which is somewhat more complex.

Other interesting research found may be covered in recent scientific archival publications [7-39], including many reviews, but currently merely out of the scope of the goal of this short communication. However, probably very valuable for continuing investigations on a multitude of aspects including economic and social implications.

Conclusions

Although this report is based on a limited amount of data, the data is quite trustworthy and therefore able to serve as a good reference, we can already conclude on important points. There is a huge potential in the amount of biomass in LvC available. Furthermore, existing efficient technologies to convert this energy source to the desired form are available, either power (electricity) or heat. However, not a real large potential for competing suppliers of small-scale gasifiers to H_2 exists yet. As LvC is estimated as having the capacity of supplying more than sufficient total energy for households it can serve industrial activities as well, probably covering everything. Bottomline is that LvC has the potential to play as a frontrunner in the energy transition. Such a region must remain aware of appearing affordable associated technology. My expectations are high on the latter issue. LvC, and thus many Dutch municipalities, can be a self-sufficient energy region based on its agri-food sector. The message holds for any community over the world if a prefactor is applied. Added literature might be used to lift implementations a step higher. The author saw it as his task to uncover this potential, not unimportant, but now the vast majority of work starts by actually liberating this potential by using it and trying to make your municipality the winning team! For local applications starting the process with even a fraction of the estimated amounts is always possible and contributes to the mitigation of the climate problem.

Ethical compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with

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the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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References

1. US Department of Energy. US Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and BJ Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 2011; 227. https://www.energy.gov/sites/default/files/2015/01/f19/billion_ton_update_0.pdf
2. Langholtz MH. personal communication. January 2023.
3. US Department of Energy. Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. MH Langholtz, BJ Stokes, LM Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 2016; 448. doi: 10.2172/1271651. http://energy.gov/eere/bioenergy/2016-billion-ton-report.
4. Lepage T, Kammoun M, Schmetz Q, Richel A. Biomass-to-hydrogen: A review of main routes production, processes evaluation, and techno-economical assessment, Biomass and Bioenergy. 2021; 144: 105920; 0961-9534. https://doi.org/10.1016/j.biombioe.2020.105920.
5. A separate database containing the disaggregated biomass supplies by county and state is available through a Web-based Bioenergy Knowledge Discovery Framework (http://bioenergykdf.net) for users to capture, visualize, and analyze information on the complete bioenergy supply chain and the infrastructure needed to support that chain (ORNL, 2010).
6. Energy consumption private dwellings; type of dwelling and regions. https://www.cbs.nl/en-gb/figures/detail/81528ENG, accessed 30-12-2022
7. Oyedeji O, Langholtz M, Hellwinckel C, Webb E. Supply analysis of preferential market incentive for energy crops, Biofuels, Bioproducts and Biorefining. 2021; 15(3):736-748
8. Li C, Aston JE, Lacey JA, Thompson VS, Thompson DN. Impact of feedstock quality and variation on biochemical and thermochemical conversion, Renewable and Sustainable Energy Reviews, 2016; 65:525-536.
9. Golecha R. Minimizing the Cost of Agriculture Waste for Cellulosic Biofuels, Strategic Planning for Energy and the Environment 2016; 36(2):14-21.
10. Golecha R, Gan J. Optimal contracting structure between cellulosic biorefineries and farmers to reduce the impact of biomass supply variation: Game theoretic analysis, Biofuels, Bioproducts and Biorefining. 2016; 10(2):129-138.
11. Golecha R. Biomass Supply Strategy for Building a Sustainable Cellulosic Biofuel Business, Strategic Planning for Energy and the Environment. 2016; 35(4):22-33.
12. Martinez-Villarreal S, Kammoun M, Richel A. The critical role of hydrogen in the development of new biofuels, Current Opinion in Green and Sustainable Chemistry. 2023; 39:100716.
13. Wu N, Lan K, Yao Y. An integrated techno-economic and environmental assessment for carbon capture in hydrogen production by biomass gasification, Resources, Conservation and Recycling. 2023; 188:106693.
14. Mould K, Silva F, Knott SF, O'Regan B. A comparative analysis of biogas and hydrogen, and the impact of the certificates and blockchain new paradigms, International Journal of Hydrogen Energy. 2022; 47(93):39303-39318.
15. Hafeez S, Harkou E, Spanou A, Manos G, Constantinou A. Review on recent progress and reactor set-ups for hydrogen production from formic acid, Materials Today Chemistry. 2022; 26:101120.
16. Eloffy MG, Elgarahy AM, Saber AN, Mohsen A, Elwakeel KZ. Biomass-to-sustainable biohydrogen: Insights into the production routes, and technical challenges, Chemical Engineering Journal Advances. 2022; 12:100410.
17. Calvo-Flores FG, Martin-Martinez FJ. Biorefineries: Achievements and challenges for a bio-based economy. Front Chem. 2022 Nov 10;10:973417. doi: 10.3389/fchem.2022.973417. PMID: 36438874; PMCID: PMC9686847.
18. Castro J, Leaver J, Pang S. Simulation and Techno-Economic Assessment of Hydrogen Production from Biomass Gasification-Based Processes: A Review, Energies. 2022; 15(22):8455.
19. Vuppaladadiyam AK, Vuppaladadiyam SSV, Awasthi A, Sahoo A, Rehman S, Pant KK, Murugavelh S, Huang Q, Anthony E, Fennel P, Bhattacharya S, Leu SY. Biomass pyrolysis: A review on recent advancements and green hydrogen production. Bioresour Technol. 2022 Oct 7;364:128087. doi: 10.1016/j.biortech.2022.128087. Epub ahead of print. PMID: 36216287.
20. Lee D, Nam H, Won Seo M, Wang S, Park YK. Recent progress in the catalytic thermochemical conversion process of biomass for biofuels, Chemical Engineering Journal. 2022; 447:137501.
21. Wijayasekera SC, Hewage K, Hettiaratchi P, Pokhrel D, Sadiq R. Sustainability of waste-to-hydrogen conversion pathways: A life cycle thinking-based assessment, Energy Conversion, and Management. 2022; 270:116218.
22. Buffi M, Prussi M, Scarlat N. Energy and environmental assessment of hydrogen from biomass sources: Challenges and perspectives, Biomass and Bioenergy. 2022; 165:106556.
23. Taipabu MI, Viswanathan K, Wu W, Hattu N, Atabani AE. A critical review of the hydrogen production from biomass-based feedstocks: Challenge, solution, and future prospect, Process Safety and Environmental Protection. 2022; 164:384-407.
24. Sridhar A, Ponnuchamy M, Senthil Kumar P, Kapoor A, Xiao L. Progress in the production of hydrogen energy from food waste: A bibliometric analysis, International Journal of Hydrogen Energy. 2022; 47(62):26326-26354.
25. Karras T, Brosowski A, Thrän D. A Review on Supply Costs and Prices of Residual Biomass in Techno-Economic Models for Europe, Sustainability (Switzerland). 2022; 14(12):7473.
26. Tezer Ö, Karabağ N, Öngen A, Çolpan CÖ, Ayol A. Biomass gasification for sustainable energy production: A review, International Journal of Hydrogen Energy. 2022; 47(34):15419-15433.
27. Karaeva JV, Timofeeva SS, Kovalev AA, Grigoriev VS, Litti YV. CO-PYROLYSIS of agricultural waste and estimation of the applicability of pyrolysis in the integrated technology of biorenewable hydrogen production, International Journal of Hydrogen Energy. 2022; 47(23):11787-11798.
28. Rosyadi I, Suyitno S, Ilyas AX, Budiono A, Yusuf M. Producing hydrogen-rich syngas via microwave heating and co-gasification: a systematic review, Biofuel Research Journal. 2022; 9(1):1573-1591.
29. Hosseinzadeh A, Zhou JL, Li X, Afsari M, Altaee A. Techno-economic and environmental impact assessment of hydrogen production processes using bio-waste as renewable energy resource, Renewable and Sustainable Energy Reviews. 2022; 156:111991.

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30. Agyekum EB, Nutakor C, Agwa AM, Kamel S. A Critical Review of Renewable Hydrogen Production Methods: Factors Affecting Their Scale-Up and Its Role in Future Energy Generation. Membranes (Basel). 2022 Feb 1;12(2):173. doi: 10.3390/membranes12020173. PMID: 35207094; PMCID: PMC8880752.

31. Wijayasekera SC, Hewage K, Siddiqui O, Hettiaratchi P, Sadiq R. Waste-to-hydrogen technologies: A critical review of techno-economic and socio-environmental sustainability, International Journal of Hydrogen Energy. 2022; 47(9):5842-5870.

32. Hassan Q, Hafedh SA, Mohammed HB, Salman HM, Jaszczur M. A review of hydrogen production from bio-energy, technologies, and assessments, Energy Harvesting and Systems. 2022.

33. Yeşilova N, Kayıkcı CBÇ, Ateş AE, Özcan HK, Aydın S, Biomass Value—Production of H2 as an Energy Carrier, Lecture Notes in Energy. 2022; 87:723-754.

34. Banerjee N. Biomass to Energy — an Analysis of Current Technologies, Prospects, and Challenges, Bioenergy Research. 2022.

35. Gonzalez-Garay A, Bui M, Freire Ordóñez D, High M, Oxley A, Moustafa N, Sáenz Cavazos PA, Patrizio P, Sunny N, Mac Dowell N, Shah N. Hydrogen Production and Its Applications to Mobility. Annu Rev Chem Biomol Eng. 2022 Jun 10;13:501-528. doi: 10.1146/annurev-chembioeng-092220-010254. Epub 2022 Apr 13. PMID: 35417199.

36. Ma Z, Liu X, Li G, Gao J, Cui P. Energy consumption, environmental performance, and techno-economic feasibility analysis of the biomass-to-hydrogen process with and without carbon capture and storage, Journal of Environmental Chemical Engineering. 2022; 9(6):106752.

37. Aziz M, Darmawan A, Juangsa FB. Hydrogen production from biomasses and wastes: A technological review, International Journal of Hydrogen Energy. 2021; 46(68):33756-33781.

38. Dovichi Filho FB, Castillo Santiago Y, Silva Lora EE, Escobar Palacio JC, Almazan del Olmo OA. Evaluation of the maturity level of biomass electricity generation technologies using the technology readiness level criteria, Journal of Cleaner Production. 2021; 295:126426.

39. Kim S, Dale BE. All biomass is local: The cost, volume produced, and global warming impact of cellulosic biofuels depend strongly on logistics and local conditions, Biofuels, Bioproducts and Biorefining. 2015; 9(4):422-434.

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