Review of screening LCA by DTU about the REnescience process in the Netherlands

Prepared for:
Cure Afvalbeheer

Screening LCA review, Final version
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Author(s):
Geert Bergsma

1 Introduction

This report describes the review by CE Delft of the screening LCA study:
Environmental Performance of REnescience in the Netherlands, LCA screening, Davide Toninie, Roberto Turconi, Thomas Fruergaard Astrup DTU, October 2014

In this LCA study the REnescience technology is compared with a conventional municipal waste incinerator. This REnescience technology is characterized by treatment of municipal waste with enzymes. This treatment step leads to a conversion of most of the biomaterial in the waste into a bioliquid which can be used to produce biogas or bioplastics. This treatment step also 'cleans' the non-biowaste, such that plastic, steel and aluminium can easier be separated and recycled.

The screening LCA study has the following characteristics:
- only greenhouse gasses and energy are evaluated;
- consequential approach: this means also indirect consequences of the technology are taken into account;
- functional unit: 1 ton of MSW generated in the Netherlands;
- modelling with LCA software Easetech.

Options considered for the comparison:
1. Direct incineration in an R1 class incinerator in The Netherlands.
2. REnescience process without material recovery.
3. REnescience process with material recovery.
4. Source separation and digestion of the bio-fraction, REnescience process for the residual fraction.

Two options were assessed for the produced biogas:
1. Biogas upgraded to biomethane and injected in the local gas grid.
2. Biogas use in a combined heat and power unit (CHP) with connection to local heat system.

2 First step, a first check, questions and answers.

During this review project the first step was a check of the screening LCA report of DTU, which led to a first impression. In a second step questions were formulated for DTU. All these questions and answers further clarified the screening LCA and are summarised in Appendix A.

First impression

The GHG analyses looks like a complete analyses with all relevant aspects in the analyses. However, the following aspects seem missing:
- the GHG emission for the production of enzymes;
- the GHG emission for the recycling process for the in the REnescience process separated plastics (up to 50% of energy value of the plastic).

Questions

There were some doubts about some quantitative data used in the analyses, which can be important for the outcome:
- The efficiency of the MSWI (did the author indeed use Dutch averages?).
- The efficiency of the CHP installation seems high compared to the Dutch mean value.
- The reference for heat (district heating is not the standard Dutch heat delivery system).

- The reference for the marginal electricity. This is not based on gas fed power production anymore in the Netherlands. We advise to use the official figures of the Dutch government (a mix of coal and gas).
- It seems that the environmental gain of plastic recycling is rather high compared to the Dutch mean value (only 10% loss).

Variations / sensitivity analyses are missing and could be done for:
- MSWI efficiency;
- CHP efficiency;
- Plastic recycling system type variations.

A Cumulative Energy Demand (CED) calculation would be interesting for the energy comparison.

A thorough reaction by DTU

DTU gave a thorough reaction to all questions.
- The efficiency of the MSWI is based on the incinerator at AVR with 13% electrical efficiency and 42% heat efficiency
- The efficiency of the CHP installation is high but in theory possible. In a full LCA for the Dutch situation the amount of heat which can be sold could be checked. Conclusion of CE Delft: The CHP option is an optimistic scenario for The Netherlands.
- The reference for heat (district heating is not the standard Dutch system) is 90% (LHV)instead of 107% (LHV) for Dutch consumer installations. Conclusion of CE Delft: The CO_2 gain of the heat delivery for the CHP option is overestimated with about20%.
- The reference for the marginal electricity. This is not based on gas fed power generation anymore in the Netherlands. We advise to use the official figures of the Dutch government (a mix of coal and gas). Conclusion of CE Delft: Due to the use of power generation from natural gas as a reference the CO_2 gains of producing electricity with the biogas of the REnescience process is underestimated.
- The environmental gain of plastic recycling seems rather high for the Dutch situation (only 10% loss). The GHG gain by plastic recycling is 1,892 g CO_2/kg plastic. Conclusion of CE Delft: This value is somewhat higher than calculated for the Dutch Plastic Heroes system (10%) but the Ecoinvent data source used is acceptable.
- The GHG emissions of the enzymes amount to 4,4 kg CO_2 eq./kg

Variations / sensitivity analyses are missing and could be done for:
- MSWI efficiency;
- CHP efficiency;
- Plastic recycling system variations.

DTU agrees this, but it did not fit in the scope of a screening LCA.

A Cumulative Energy Demand (CED) calculation would be interesting for the energy comparison.
The DTU agrees, but it did not fit in the scope of a screening LCA.

3 Second step, review including the answers of DTU

The reaction of DTU answers all questions of CE Delft. With the answers included, it seems that all relevant aspects for a screening LCA study are present. Most used data is correct without need for discussion. Some data are open for some discussion:
- The CHP option: The CO_2 value of the heat produced seems overestimated. This, combined with the fact that it is not likely that a CHP installation will be applied in a future Renescience installation for CURE in Eindhoven.

– The reference power production option: The CO_2 value of the produced electricity is underestimated in the calculations, because the current marginal mix in The Netherlands also contains coal.

With the effect of electricity underestimation and heat overestimation the net combined result for the different options will not change much. All options produce heat and electricity in a similar relationship so the conclusion will not change much by changing this values we expect. In a full LCA specific for the Dutch situation this could be checked in more detail.

The reactions of the DTU lead us to the conclusion that the non-CHP based calculations are a good first screening LCA result to compare the technologies. The CHP option could be used if more details are knownof a planned CHP installation at the REnescience installation for CURE. (Cure Afvalbeheer stated that there are no plans to build a CHP installation)

4 Input by Nowit and Dong

In addition to the answers from DTU on the LCA questions we also received extra information from Dong via Nowit about the technology and the parameters. Dong explained that for the screening LCA conservative values for the biogas yield were used. Also conservative values for the energy need were used. They expect that in the future a better performance of the installation can be reached which will both improve the environmental and the economic performance.

Three important factors were described:
- The actual output of biogas from the enzyme reactor and digestion installation can probably be improved by a factor 2.
  This production of biogas is much higher than the ONF option which Attero/Omrin uses without enzymes due to the different nature of the process and bioliquid.
- The mix of added enzymes is planned to be changed in the future into a less expensive one with less CO_2 footprint
- The heat balance of the installation offers room for improvement.

All these factors are important for the LCA results and are to be checked in future sensitivity analyses. The biogas production figures are important such that we decided to check them in this review.

5 Calculation check: extra biogas and enzymes production.

In a REnescience installation 89 Nm^3 methane is produced with a tonne of waste. (Figure used in the screening LCA). Because this is an important parameter we compared this with the reports from Attero and Omrin who also produce biogas from waste, but without enzymes.

Attero ONF

Attero has an installation working also with Dutch waste in Wijster, which separates the organic wet fraction from the waste and produces biogas with this fraction without using enzymes. Attero claims to produce 4.6 mln Nm^3 of methane annually with the Wijster installation.[1] This Wijster installation has a capacity for treating 810,000 ton per year. This is separated into 56,000 tonne

[1] http://www.attero.nl/nl/producten-diensten/projecten/onf-vergister-wijster/

ONF. This means that only 6 Nm3 of methane is produced from a tonne of waste (4.6 mln/0.81 mln).

Omrin ONF
Omrin communicates that 10 mln Nm^3 biogas is produced using their technology. This results in 6.5 mln Nm^3 methane gas. Omrin has a capacity of 228 kton of waste. This results in a production of 28.5 Nm^3 methane gas per tonne of waste. (6.5 mln./0.228 mln.)

REnescience produces 15 times more biogas than Attero ONF and 3 times more than Omrin
The REnescience technology produces 15 times more biogas from a tonne of waste than the Attero installation and 3 times more than the Omrin installation. This can be explained by the following factors:
- all biomass containing waste is treated, not only the part separated into ONF (7% for Attero);
- also paper is treated;
- application of enzymes lead to free sugars and acids, which are more easily converted into bio-gas.

CO_2 gain biogas compared with CO_2 emissions enzymes and electricity
With a CO_2 emission factor of 1,825 kg/Nm^3 the extra gas production can also be compared with the CO_2 emissions from the production of the enzymes
- Attero: CO_2 avoided extra biogas 1,825 x (89-6) = 151 kg CO_2/tonne waste;
- Omrin: CO_2 avoided extra biogas 1,825 x (89-28,5) = 110 kg CO_2/tonne waste;
- CO_2 caused by enzymes 4,4 x 9 kg = 39,6 kg /tonne waste.

The CO_2 value of the biogas is 2,8 to 3,8 times higher than the CO_2 burden of the enzymes used. But also the energy the produced by the incinerator is reduced which leads to a loss of CO_2 gain by around 150 kg CO_2 also.

Results extra gas production or less enzymes
This indicative calculations learn that the methane production or REnescience is much higher than that of the ONF option of Attero and reasonable higher than that of Omrin. But with REnescience you need enzymes and the energy production from incineration is reduced more. Especially the effect of an eventually extra biogas production will considerable the LCA results. Doubling of the yield may result in an extra of 150 kg CO_2 per tonne of waste.

Conclusions gas, enzymes, electricity
Without extra recycling of materials (scenario 2) and with the conservative assumption for biogas the REnescience installation poses no environmental gain compared to the best state-of-the-art of OMRIN (page 19). With a doubled gas production, better enzymes and an optimized heat situation this will changed into an improved performance compared to the best current technology. It would be of interest for the Dutch situation to confirm this.

The installation based on the current assumption of extra material recycling (scenario 3) results in an environmental gain compared to the best available technology in the Dutch market,.

6 Recycling/ circularity focus

The decicive environmental gain by the REnescience installation is caused by the additional recycling of 72 kg plastic, 5 kg steel and 2,5 kg aluminium. The income for these streams is topped up by the Dutch government with subsidies for the plastic fractions. Since 2015 there are additional subsidies for beverage carton recycling in the Netherlands but this can nog be used here because the paper is digested in the REnescience process and beverage carton cannot be readily separated before entering the process. Because the plastic fraction is 5 to 10 times higher than the carton fraction this is only a minor financial loss.

7 Other technologies?

Aluminium
The installation leads to 50% more aluminium recycling (7,5 kg instead of kg/tonne). Other installations MSWI claim similar improvements with the Inashco technology.

Plastics
The REnescience installation claims 72 kg plastic for recycling per ton.
This is higher than the amount by Attero but the difference is not very large. Extra plastics Attero, 23 a 31 kg/househoulds = 46 a 62 kg per tonne.

Especially the Omrin installation which also produces a considerable amount of biogas but does not need enzymes and produces plastic and aluminium is a competitor of the REnescience technology.

Although an LCA comparison with Omrin is not carried out the figures show that we the environmental gains will probably be close.

8 Conclusions Review Screening LCA

Biogas to Biomethane or biogas to CHP: Advise to look at Biomethane
In the LCA two options for using the biogas are calculated. The results for the CHP option are better for the REnescience option than the Biomethane option. Because it is uncertain if a combined heat and power facility will actually be built by Dong for the Cure unit and because a CHP can also be built for natural gas with the same environmental gains (difference between assessment 1 and 2) we propose to judge the environmental performance based on the calculations without the CHP option. This advice is also in the light of the knowledge that today the commercial situation for CHP units in the Netherland is very difficult(high gas prices combined with low electricity prices).

Results
The screening LCA shows that the REnescience technology combined with extra recycling of plastic, steel and aluminium performs better than a conventional incinerator with energy production. This difference is not so large that we know for sure that other technologies cannot reach this gain also.

With increased performance (Dong claims of extra bio-gas, better thus less enzymes, and better heat efficiency) this difference can become more significant. This leads us to the conclusion that the REnescience has in the current status a good environmental performance probably at least comparable with other separation technologies and that REnescience process has room for improvement by innovation and then may perform better than other technologies.

It would be of interest to compare the REnescience in an LCA study with the Omrin and Attero separation installation. With the current information we expect that REnescience and Omrin will perform close. Only a complete LCA for the Dutch situation can result in a definitive comparison with the Omrin technology.

LCA

We conclude that the screening LCA of DTU is of good quality.
Due to the fact that the LCA is a screening LCA some interesting aspects for a complete analyses are still missing:

- A sensitivity analyses to see what factors are important and to check how robust the conclusions are.
- A Cumulative Energy Demand analysis to check the energy balance.
- Tables with exact numbers (quantitative results were exclusively reported in the form of graphs .
  Only net result were reported using exact numbers).
- A comparison with other waste separating technologies.

9 Suggestions

For a fair comparison of the REnescience technology with other technologies on the Dutch market (Attero, Omrin, Inashco) we advise a follow-up of the screening LCA with a full LCA with:

- An LCA for Dutch situation with sensitivity analyses and performance improvement also in the study;
- A comparison with other separation technologies (Attero, Omrin, Inashco).

Annex A LCA screening: questions from the Netherlands for DTU

Subject	LCA screening: Questions from the Netherlands for DTU
To	DTU Miljø (Thomas Astrup, Roberto Turconi, Davide Tonini)
Copy	
From	Thomas Krüger
Regarding	Comments/questions for the LCA screening

Hi Roberto,

The following questions/comments for the Dutch LCA screening for REnescience have been received. Could you please provide your comments/answers?

BR Thomas Krüger

Reply from DTU in blue

Doubts/questions per page?

1. Page 7: CHP with 40% net electricity efficiency and 50% heat efficiency seems very optimistic. This is a large CHP plant with a good contract for the heat with low temperature (no seasonal variations in demand)

The values correspond to a new small gas engine which can reach 88-96% net total efficiency and 40-48% electricity efficiency (Energi Styrelsen & Energinet.dk, 2012, page 54), and we considered optimal positioning of the plant (thus high heat recovery). This is consistent with the state-of-the-art assumption for the Dutch MSWI plant (see question 7). Seasonal variations in heat demand were not taken into consideration, as they will depend on local conditions (e.g. whether heat is used for heating or for an industrial process). In a full LCA study (rather than a screening), these aspects could be implemented based on detailed data on the local market for heat.

2. Page 9: Natural gas fired power plant is seen as marginal technology (reference 2011). Because of the high gas prices this is much more complex in the current Dutch electricity market. The amount of coal has gone up. We suggest to use a mix of gas and coal or to use the figures provided by the government. (RENEWABLE ENERGY MONITORING PROTOCOL, Update 2010[2])

We acknowledge that the choice of the marginal can be debated. Identifying marginal technologies is a challenging task, even more so for electricity, due to the complexity of the market and the influence of renewable energy policies. Ideally, the choice should be based on a large consensus between all stakeholders involved in the study, as different approaches are available for identifying the marginal electricity of a system.

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[2] http://www.rvo.nl/sites/default/files/bijlagen/Renewable%20Energy%20Protocol%20Monitoring%202010%20DEN.pdf

Met opmaak: Nederlands (standaard)

We followed historical trends, as suggested by Schmidt et al (2011) and Turconi et al (2011): natural gas was chosen as the marginal as it is the most fluctuating source (varying over time) (Figure 1). Further investigations on this topic is clearly a priority, as it was pointed out in the "goal and scope definition" and "limitations and further research" sections.

However, please note that if coal was the marginal for electricity, then the waste refinery scenarios involving CHP production (Assessment 2, see Table 5 or Figure 13 at page 25) would be even more beneficial than incineration (scenario 1) as it stands now. This is because: (i) the waste refinery scenarios generate more electricity and (ii) the GHG emission factor of coal is about 1.7 that of natural gas (1100 g CO_2-eq./kWh_{el} vs 643 g CO_2-eq./kWh_{el} for natural gas).

Regarding the suggested document from the Dutch government: as we are performing consequential LCA we should focus on the marginal electricity source, i.e. the technology likely to respond with a change in production as a consequence of a change in demand. The emission factors provided in the document (Table 3.3 and Table F1) are not applicable, because they refer to the average electricity production in the Netherlands rather than the marginal source. See (Ekvall & Weidema, 2004) for further information on consequential LCA approach and choice of marginal technologies.

3. Page 10: The marginal technology for heat is gas based district heating with an efficiency of 90%. This is not correct for the Dutch situation where district heating has only a small market share. A High efficiency gas powered installation should be the reference with an efficiency of 107% (see also the monitoring protocol)

As mentioned in the text, we acknowledge that the heat demand is strictly related to local conditions. Again, a more detailed modelling could be performed based on more detailed data on the local heat market. This should not be average data, but rather data associated with the responding plants in the local market (local area) where the technology would be established.

4. Page 10: Loss in recycling: The loss in recycling mainly by energy use in the Dutch plastic recycling system seems higher than the assumption here of 10% (in general 50%)

We are not sure what a 50% "loss in recycling mainly by energy use in the Dutch plastic recycling system" refers to.

The value reported (10%) refers to the loss in quality of the plastic after recycling (e.g. polymer cross-contamination, degradation, etc.), not to the energy use. Energy use at the recycling plant is accounted for in the recycling process (i.e. through the consumption of electricity, 90 kWh/t_{scrap}).

It should be noted that the total amount of plastic recycled is much lower than the plastic content in the input waste, as the sorting efficiency varies between 26% and 67% depending on the type of plastic.

5. Page 10: Aluminium and copper are more and more separated from Bottom ash. It is not clear if this is in the model. On page 12 AL and Fe are mentioned but Copper is missing.

Only recovery of Fe and Al was considered. Current inventory data on Copper recovery and recycling are limited, we therefore excluded it from the analysis.

6. Page 11: Is this eco-invent 2.2. Is this different in eco-invent 3.1?
Ecoinvent v2.2 was the latest available version at the time of the study.
In case of a future study (full LCA), we will use the latest version available.

7. Page 12: What is the assumed efficiency of the MSWI installation for electricity and heat. Are this actual Dutch values (the Danish are higher). On page 26 it seem to be 13% electricity and 42% heat, this is different from the Dutch average)
As explained in the introduction section of the report, the comparison is performed against the AVR incinerator (Rotterdam, efficiency 13% electricity and 42% heat), as suggested by DONG Energy. This is consistent with the consequential LCA approach.

8. Page 14: Why does the digestate burning not result into energy (to wet?)
Correct. Digestate has very low dry matter content (about 4-6%). Current practice involves mechanical dewatering up to 22-25% total solids, so that the combustion occurs with no energy consumption (net energy balance is zero). This is established practice when combusting digestate.

9. Page 17: For energy the exergy approach is suggested. Why did you not calculate the Cumulative energy Demand (CED) in which electricity is also more valuable than heat.
The current LCA screening includes GHG emissions and energy balancing, but neither exergy nor CED calculations were included.

The exergy approach was suggested because it allows evaluation of the efficiency of the waste-to-energy process (i.e. the results do not depend on the marginal electricity and heat chosen). CED calculates the total primary energy demand of electricity and heat consumed or produced, thus the results are dependent on the marginal electricity and heat. Depending on the objective of a specific assessment, both exergy balance and CED method can be useful tools.

10. Page 19: It is suprising that scenario 2 is performing worst. In a CE Delft study an alternative process of Attero with ONF separation and digestion is performing better than an MSWi?
We do not have information on (i) waste characteristics, (ii) waste management system, (iii) process parameters and (iv) modelling approach, thus we cannot comment on the results of the CE Delft study. There may be good reasons for the differences.

As stated in the discussion sections, in Assessment 1, waste incineration (scenario 1) outperforms the waste refinery without plastic recovery (scenario 2), as the additional energy consumption of the waste refinery is not compensated by higher energy recovery. In assessment 2, scenario 1 and 2 have similar GHG performance. In both assessments, scenario 2 performs worse than 3 and 4 because plastic is not recovered and recycled, and the fossil carbon of the plastic is emitted as CO_2 after incineration.

11. Page 19: How do scenario 3 and 4 perform if the plastic recycling is resulting in less environmental profit (50% loss in Plastic heroes system)
This is certainly a good suggestion for a sensitivity analysis in a future study. Sensitivity analysis on key parameters should be part of a full LCA study, thereby evaluating the robustness of the results. Sensitivity analysis was not part of the LCA screening. As you suggested potential areas that could be further investigated are: (i) substituted electricity and heat, (ii) energy efficiency of MSWI and CHP, (iii) plastic recycling. The full list of sensitivity analysis scenarios should be agreed upon by the stakeholders.

First conclusion of the review

The GHG analyses looks like a complete analyses with all relevant aspects in the analyses. The following aspects are missing:

1. The GHG emission for the production of enzymes

This is included in the study, 4.4 kg CO_2-eq/kg$_{enzymes}$

2. The GHG emission for the recycling process for plastics (up to 50% of energy value of the plastic)

Recycling of plastic was credited by substitution of virgin material provision, 1892 gCO_2-eq/kg plastic (Table 2, from Ecoinvent database).

But we have doubts about some data used in the analyses which can be important for the outcome:
- The efficiency of the MSWI (did you use Dutch averages?)
- The efficiency of the CHP installation seems high.
- The reference for heat (district heating is not the normal Dutch system).
- The reference for the marginal electricity. This is not gas any more in the Netherlands. We advise to use the official figures of the Dutch government (mix of coal and gas).
- It seems that the environmental gain of plastic recycling is rather high (only 10% loss).

The issues raised in points 14-18 have been addresses in the answers to 1-11.

3. Variations, sensitivity analyses could be done for:
- MSWI efficiency;
- CHP efficiency;
- plastic recycling system variations.

Agreed (see 11).

4. A Cumulative energy Demand (CED) calculation would be interesting for the energy comparison.

Agreed (see 9).

Bibliography

Ekvall, T., & Weidema, B. P. (2004). *LCA Methodology System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis*, 9(3), 161–171.

Energi Styrelsen, & Energinet.dk. (2012). *Technology data for energy plants*.

Schmidt, J., Thrane, M., Merciai, S., & Dalgaard, R. (2011). *Inventory of country specific electricity in LCA - consequential and attributional scenarios*. Aalborg.

Turconi, R., Butera, S., Boldrin, A., Grosso, M., Rigamonti, L., & Astrup, T. (2011). *Life cycle assessment of waste incineration in Denmark and Italy using two LCA models*. *Waste Management & Research*, *29*(10 Suppl), 78–90. doi:10.1177/0734242X11417489