CURE waste testing in REnescience pilot plant

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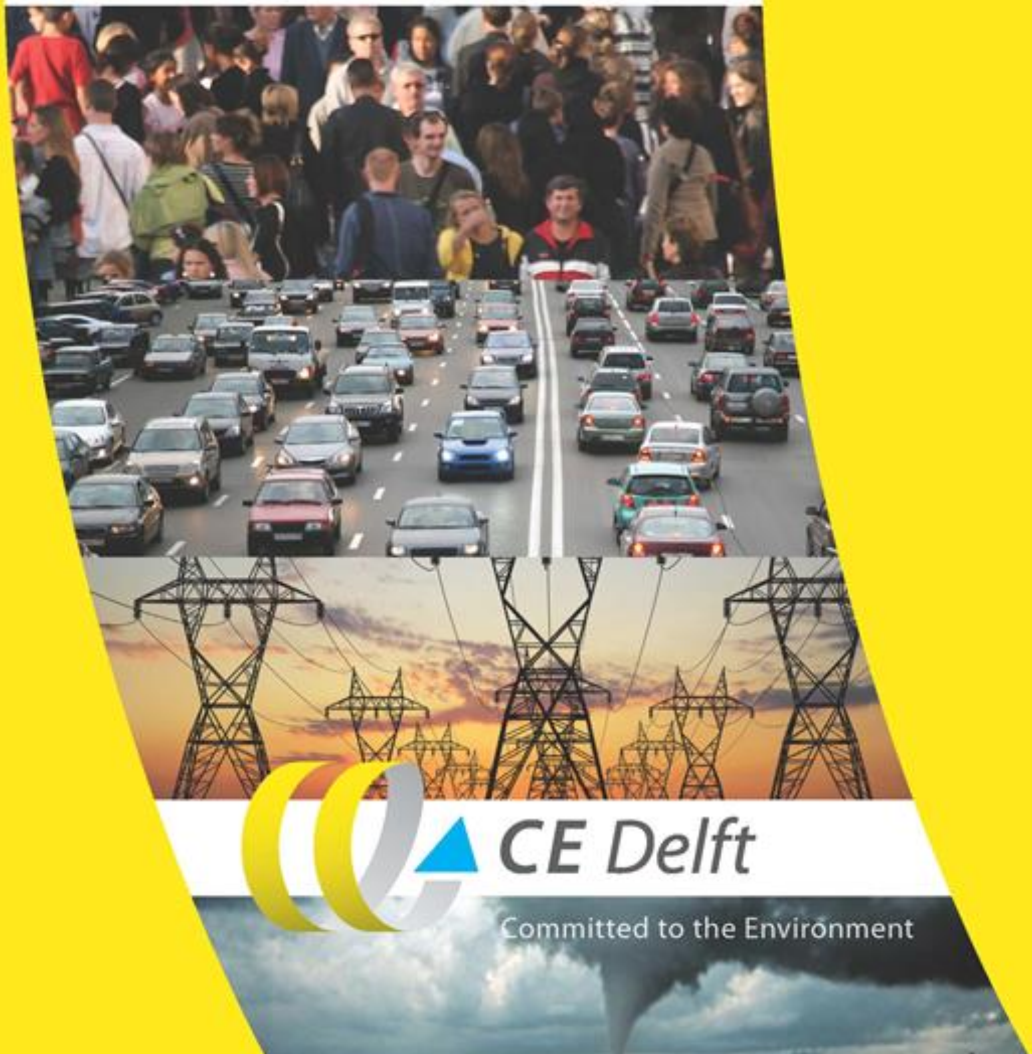
Local assessment by Diederik Jaspers
Final report



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Further information on this study can be obtained from the contact person, Diederik Jaspers.

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Summary

In November 2015 REnescience-Dong has performed pilot plant tests based on their novel enzymatic waste process on four practical batches of municipal solid waste from CURE Afvalbeheer. The goal of these tests is to support the feasibility and preliminary business case for the full scale process, which is based on the expected waste composition of CURE Afvalbeheer.

This report provides a view of CE Delft on the results of the pilot plant test performed with 120 tons of CURE waste in Copenhagen as provided by REnescience-DONG and presented in the meeting of February 11th at CURE in Eindhoven.

The following findings were obtained:

1. The input waste batches used in this pilot plant test show a fair similarity in degradable biomass compared to CURE waste streams of apartments analysed in the period 2013-2014, but deviates from what was earlier expected by REnescience-Dong. The water content proved to be high thus the dry matter content was only 54% instead of the 61% expected amount. The biomass and paper and cardboard fractions were relatively low with -31 and -47% points less than expected. The plastic- and metal content of the apartment waste batches were about 20% higher than expected. One waste batch of CURE showed too much deviation to be representative and is not to be used as a basis.

2. Based on first measurement results of pH and COD the pilot seems to have reached sufficient stability (steady state) for the two settings of retention time.

3. The results of major analyses for the above mentioned goal indicate that in line with the lower amount of biomass in the feed a similarly 22% lower gas potential was present in the bio-liquid yield than earlier expected. Also, the increased amount of plastics was also found in the output in the recovery of plastic foils (2D) and more rigid plastics (3D), which showed an 21% increase. It is interesting to know how this affects the LCA. The metal output was 21% higher. Brine output was much higher with 57 kg/ton of feed but this was caused by the larger wash water flow in this pilot system.

4. Thus, when the deviations in the feed are taken into consideration, the pilot plant did perform well and in general the results found were as expected. The mass balance of the pilot tests showed an excellent fit with only 1 and 3% deviation for the two runs respectively. The heat balance data were not yet available at this time.

5. The next step of upscaling to full scale is to be started by REnescience-Dong based on these initial data. These data are to provide the interface with the anaerobic digestion and to set up new and more precise mass and heat balances. In parallel, the business case needs to be continuously refined during this scale up. If structural deviations in the waste composition occur, new pilot tests are recommended.

To support this business case refinement process it is recommended to regularly perform waste analyses on current CURE waste samples from both

apartments as well as from homes. This, also including measurement of the water content.

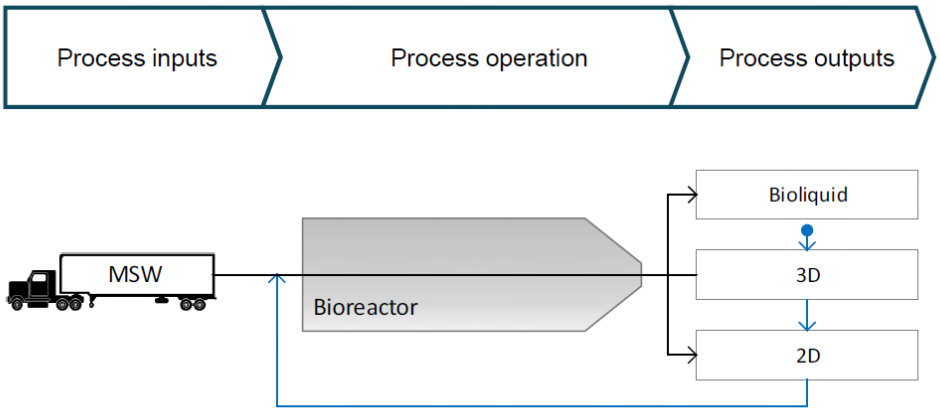
1 Introduction

1.1 The REnescience process

The REnescience process is designed to process a broad range of municipal solid waste (MSW). The main part of the biomass fraction in this MSW is converted into a bio-liquid by action of a mixture of potent enzymes.
The lignocellulose and fibrous fraction are not converted and of the lignocellulose can have an inhibiting effect, which may require extra dosage of enzymes. Therefore, deviations in the composition of biomass in the MSW of the feed will play a significant role in the performance of the process.
The resulting bio-liquid will be successively converted into bio-methane suited for feeding into the natural gas grid, but this is **not** part of this pilot plant.

Non-biomass fractions comprise 2D and 3D plastics and inorganic material are washed and separated in successive steps. Please refer to the overview of the pilot plant in Figure 1.

Figure 1 Overview of current REnescience pilot plant



1.2 Goal of the pilot tests with waste of CURE Afvalbeheer

Over the past years the REnescience pilot plant was tested with mainly apartment waste from the area around Copenhagen. Because it is currently not precisely known how waste of CURE Afvalbeheer will differ from the previously tested waste of apartments in Copenhagen it is important to determine the effect of this difference. Therefore actual waste of CURE is tested in the pilot plant in two runs:

1. A short retention time (fast processing) of 12 hours.
2. A normal retention time (normal processing) of 18 hours.

From the CURE operating area near Eindhoven the following two waste sources are envisaged for the *full scale* REnescience process:

1. Apartment and office waste.
2. Private homes with gardens.

It was decided **to exclusively test the first source of apartment waste only**, which will show similarities with the apartment waste from Copenhagen. The second comprises biomass fraction (GFT-vegetable, fruit and garden waste) with a larger wood (lignocellulose) fraction. Cause is that although the garden fraction is collected separately, part of the garden waste will end up in the MSW and thus in the REnescience process. The resulting larger lignocellulose fraction may affect the REnescience process and it is of particular interest to check its impact for reasons of mitigation during practical operation of the process i.e. an increased dosage of enzymes during limited periods of time of increased lignocellulose and the related effect on the business case.
It was decided **not** to include this CURE waste type but test this effect in a later stage in a smaller scale test with controlled fractions of lignocellulose.

Additionally, the time between collection and processing will differ in practice e.g. by weekends, holidays, maintenance and other reasons for stops. As a result different states of natural degradation of the biomass i.e. by fungal and bacterial micro-organisms will occur also depending on temperature of storage. It is likely that these processes can affect and compete with the enzymatic and biological activity in the REnescience process.
Also, it was decided that this variable is **not** tested during these trials and will be tested later on a smaller scale with a controlled age, while the collection and import of the CURE waste samples from The Netherlands to the pilot plant in Copenhagen already takes a lot of time, which blocks testing of 'fresh' CURE waste samples.

For the heat balance the heat capacity of the waste input is an important factor. This value can vary with composition and moisture content and can greatly determine the energy consumption of the process at cold/freezing temperatures during winter time. The occurrence of pre-digestion ('broei') results in pre-heating of the waste. This reduces the heating power required for the feed in the process. The business case is largely affected by the heating power values during stable phases of the tests.

The value producing fractions in the earlier drafted business case can be validated with the quantities of fractions produced in the pilot plant.
Main value produced is the amount and biogas producing potential of the bio-liquid produced per ton of CURE waste. This is not tested but analysed on a sample. Additionally, the efficiencies of conversion per fraction of CURE waste provide additional view on the value streams produced in the pilot plant.

The analyses of the business case and the anaerobic digestion system are not performed by CE Delft and not part of this report.

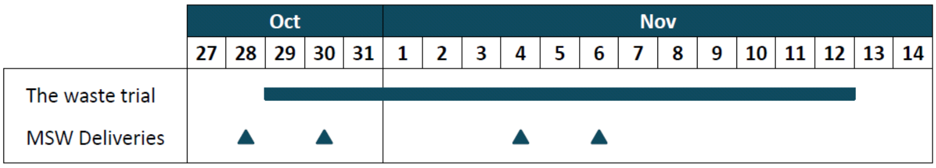
The upscaling of the pilot plant is not yet clear for the author, so an outlook on the conversion of the value streams to this full scale cannot be given yet and requires further study during the upscaling.

2 Waste input observations

2.1 CURE waste input batches

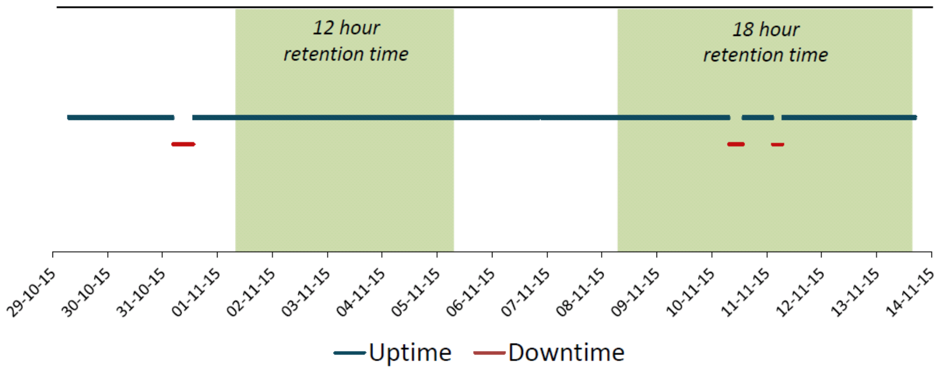
The waste of CURE was transported from the Netherlands in different batches, as described in Figure 2.

Figure 2 Planning of supply of CURE waste batches



The supply of these batches comprised 120 tons in total and provided for continuous operation for fifteen days. Only short stops occurred associated with removal of irregular objects in the waste resulting in 92% uptime, see Figure 3.

Figure 3 Uptime and stops of pilot plant operations on CURE waste



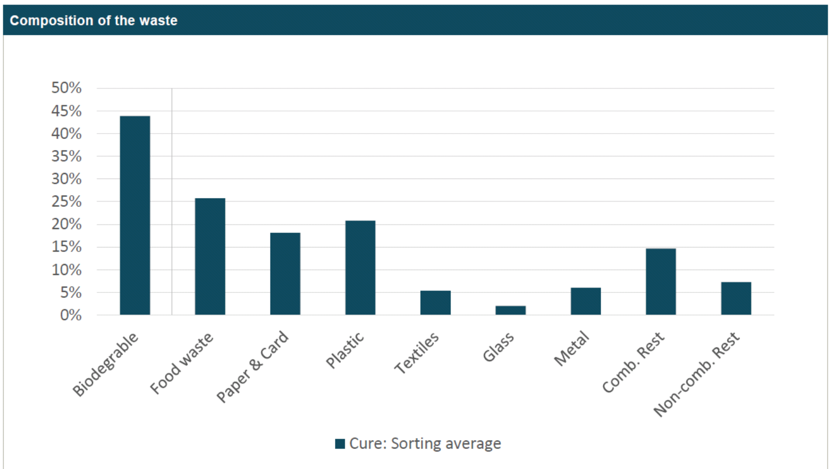
A thermal image of one of the batches showed a temperature of 35-40°C, probably due to pre-digestion.

CE Delft visited operation of the pilot plant during both retention times. Information obtained by CE Delft on these pilot plant tests comprise:
1. Waste input analyses of Afval Spiegel provided by CURE.
2. Data and information provided by REnescience-Dong.
3. PowerPoint presentation ‘First look at the REnescience waste trial on CURE MSW’ provided by REnescience-Dong.
4. Pictures during the two visits taken and provided by REnescience-Dong.
5. Own observations, which act as the basis for this report.

The composition of waste batches was analysed by order of CURE, prior to transportation to Copenhagen. This was executed by Afval Spiegel.

The overall mean results of these waste fractions of all CURE batches are shown in Figure 4.

Figure 4 Results of waste fraction analysis delivered CURE waste batches



Biodegradables: Total food waste, paper and cardboard

Per batch the waste analysis of Afval Spiegel is given in Table 1.

Table 1 Composition of CURE waste batches used in the pilot plant tests

Aandeel in fijn restafval	Hoogbouw inzameling 23-10-2015	Hoogbouw inzameling 26-10-2015	Hoogbouw inzameling 29-10-2015	Hoogbouw inzameling 03-11-2015	Hoogbouw inzameling 05-11-2015
Component	%	%	%	%	%
Groente-, fruit- en tuinafval	29,6	42,2	21,0	34,2	35,9
Papier en karton	10,5	8,4	14,1	9,3	16,4
Hygiënisch papier	11,0	6,9	9,1	4,3	5,7
Drankkartons	3,1	2,4	2,0	2,1	2,6
Kunststoffen	22,1	16,4	24,6	21,7	19,3
Glas	4,7	1,6	1,3	2,1	0,4
Metalen	8,3	4,0	8,8	4,2	4,7
Textiel	2,7	3,7	7,6	4,8	8,0
Puin en keramiek	1,5	7,1	2,5	0,0	0,3
Hout	1,9	1,5	1,5	2,0	0,7
Klein chemisch afval	0,0	<0,1	<0,1	0,0	0,1
Wit- en bruingoed	0,2	0,2	1,2	0,7	0,5
Overig afval	4,5	5,5	6,2	14,6	5,5
Totaal	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**
Subanalyses	%	%	%	%	%
Groente-, fruit- en tuinafval					
- tuinafval	3,6	12,6	2,3	7,4	8,3
- groente- en fruitafval	26,0	29,7	18,7	26,8	27,5
Hygiënisch papier					
- luiers	5,0	3,0	5,0	1,2	3,0
- overig hygiënisch papier	6,0	3,9	4,1	3,0	2,7
Kunststoffen					
- zachte kunststof verpakkingen	7,1	5,7	8,2	6,1	5,4
- harde kunststof verpakkingen	8,3	5,5	12,2	6,0	5,0
- zachte kunststof niet-verpakkingen	1,5	0,8	0,4	3,1	3,6
- harde kunststof niet-verpakkingen	1,6	1,5	1,0	2,0	2,6
- vuilniszakken en andere zakjes waarin afval is aangeboden	3,7	2,8	2,7	4,5	2,7
Metalen					
- ferro metalen verpakkingen	3,5	0,7	<0,1	1,6	2,6
- non-ferro metalen verpakkingen	1,8	1,5	5,3	0,6	0,1
- ferro metalen niet-verpakkingen	0,9	1,4	3,4	1,8	1,2
- non-ferro metalen niet-verpakkingen	2,2	0,4	<0,1	0,1	0,7

Conclusions on waste input batches

In general, compared to CURE waste analyses over 2013-2014 these five batches show a **normal mean amount of degradable biomass** (vegetables and fruit waste or GF and paper/cardboard). The **mean amount of garden waste** and the **mean amount of plastics is about 50% higher** than over this past period.

One batch deviated from the rest: 'Hoogbouw inzameling 29-10-2015', which showed about 50% less degradable biomass (vegetables and fruit waste or GF), about 75% more plastics and about 40% more paper and cardboard than the mean of past period of 2013-2014. The cause is still under investigation. Therefore, conversion results from this batch are left out of this evaluation.

Figure 5 and Figure 6 show the overall mean input feed characteristics:

Figure 5 Average input composition of biomass

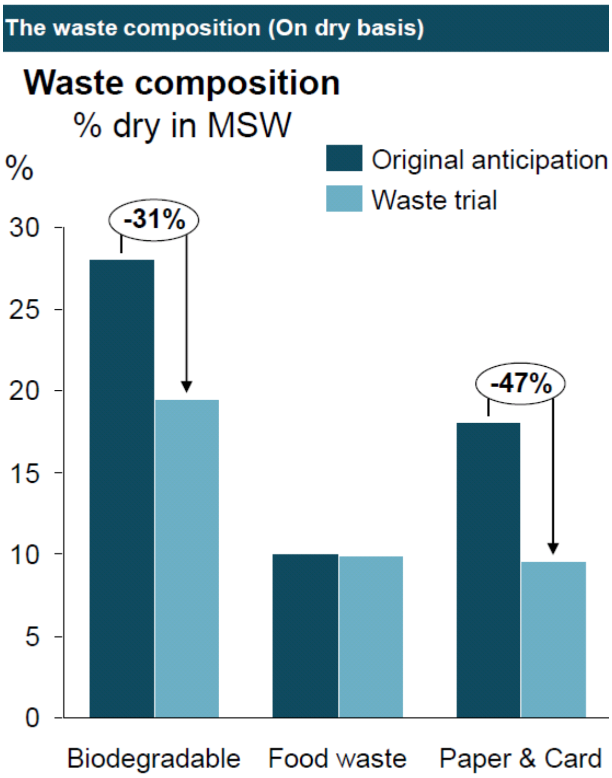
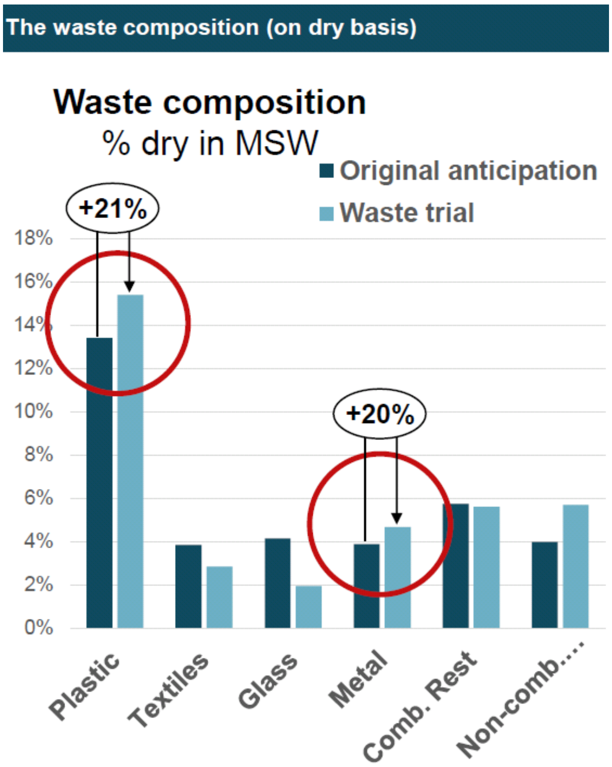


Figure 6 Average input composition of plastics and metals



3 Operational pilot plant results

The following analysis results indicate how the process has run with the CURE waste batches fed to the reactor:

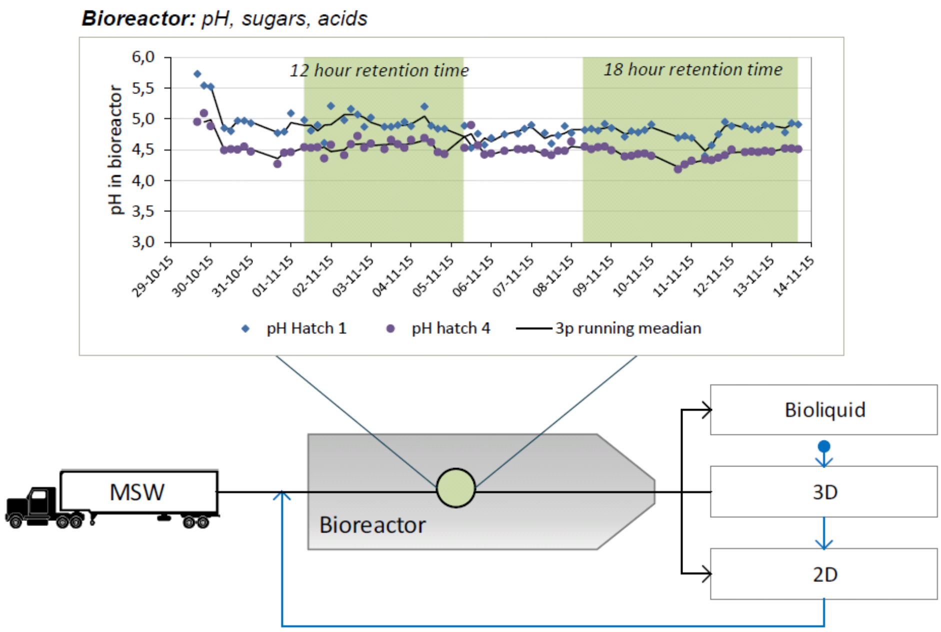
1. pH.
2. Chemical Oxygen Demand (COD, a sum parameter of organic content).
3. Gas potential of bio-liquid.
4. Component analyses of bio-liquid
   (HPLC analysis results on sugars and acids were not yet available).
5. Mass fractions on output.

The parameters pH and COD were easy to measure and gave quick results. REnescience-Dong has indicated that based on their earlier test experience these two values give a good first indication of the state of the process.

3.1 Steady-state of the process

Based on pH measurements of the process liquid in the reactor the following results were obtained, refer to Figure 7.

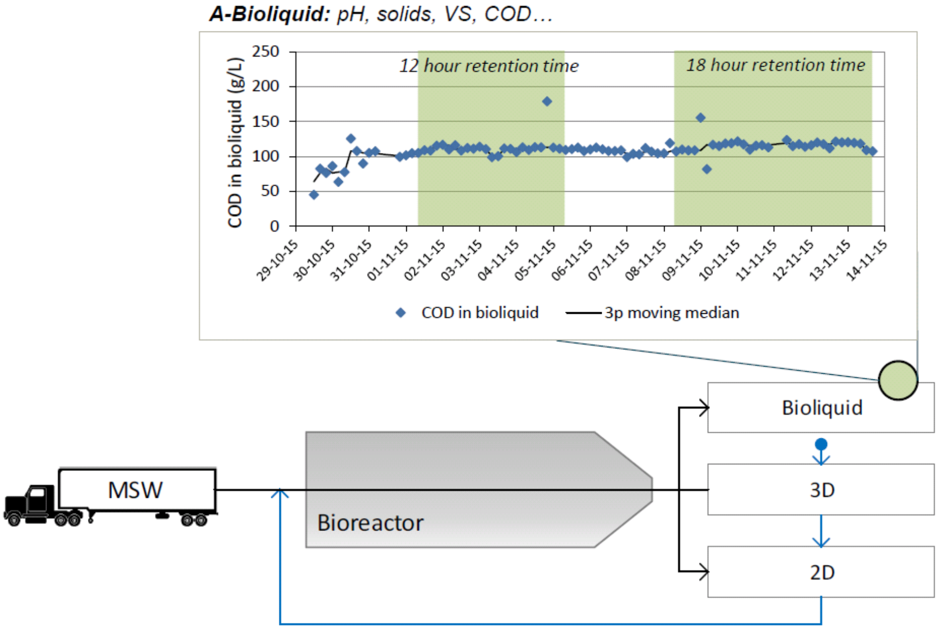
Figure 7 pH of process liquid in the reactor



Based on these measurements, after a start-up period of two days the pH remains stable apart from an outlier at the moment of a short stop.

The COD of the resulting bio-liquid during operation is given in Figure 8.

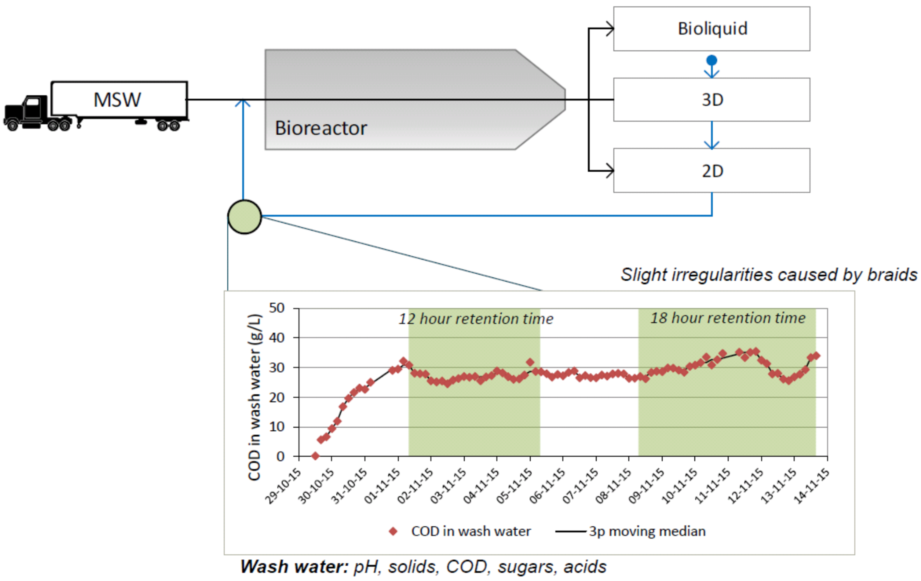
Figure 8 COD of the produced bio-liquid



After a two day's start-up period the COD became stable. The three outliers are most likely related to deviations in the COD analysis and not relevant.

And the COD of the wash water feedback system is shown in Figure 9.

Figure 9 COD of the wash water



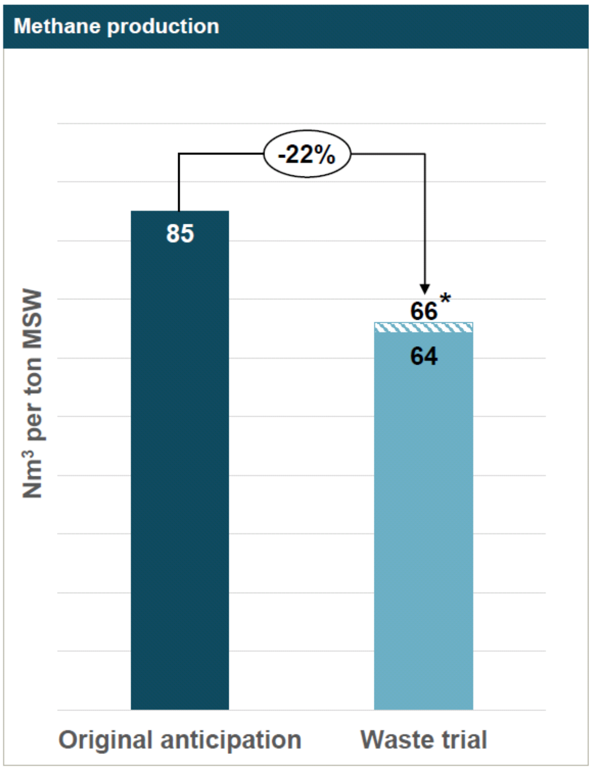
Here, after four days this system showed a stable COD level during the tests. Only between November 12th and 14th a temporary dip in the COD level occurred for which REnescience-Dong reported this was caused to braids in the feed.

Conclusion on steady state: Based on the above mentioned pH and COD measurements, the operation of the pilot reactor with batches of CURE waste seems stable from November 2nd (four days from start) until November 11th. Definitive conclusions are to be drawn when analyses of the biogas production and produced fractions become available.

3.2 Gas potential of the bio-liquid

The results of the gas potential of the bio-liquid obtained with the CURE waste batches are shown in Figure 10.

Figure 10 Average methane gas production from bio-liquid

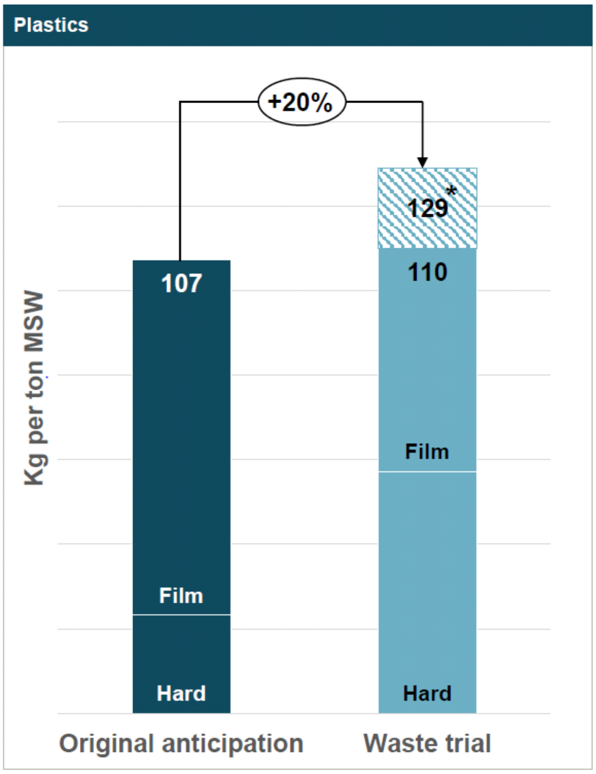


As anticipated from the less biomass input the gas potential output is lower in about the same extend.

3.3 Mass fractions of the output

Figure 11 shows the mass fractions of the output:

Figure 11 Average hard and film plastic in the output



As anticipated from the increase in the input here the output also shows a similar increase. This increase is fully present in the hard plastics fraction.

Figure 12 and
Figure 13 show the average metal, inert, RDF and brine content of the output streams.

Figure 12 Average metal content in the output

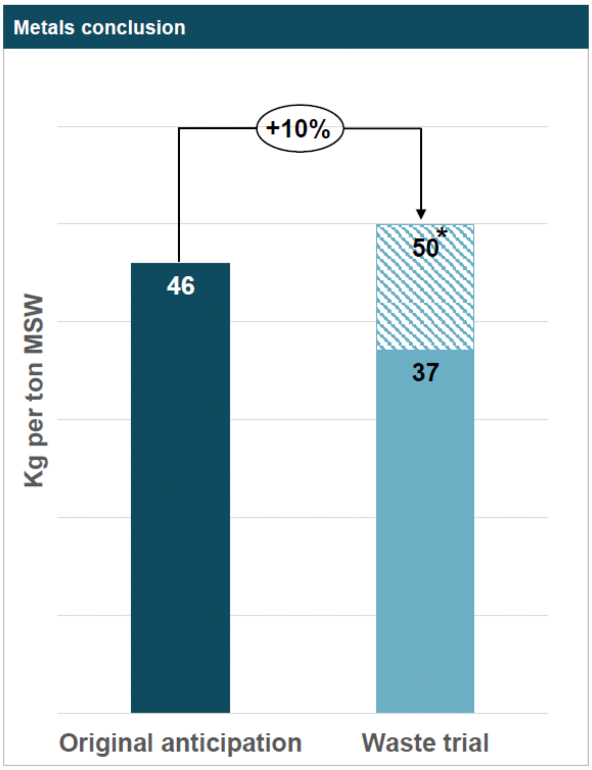
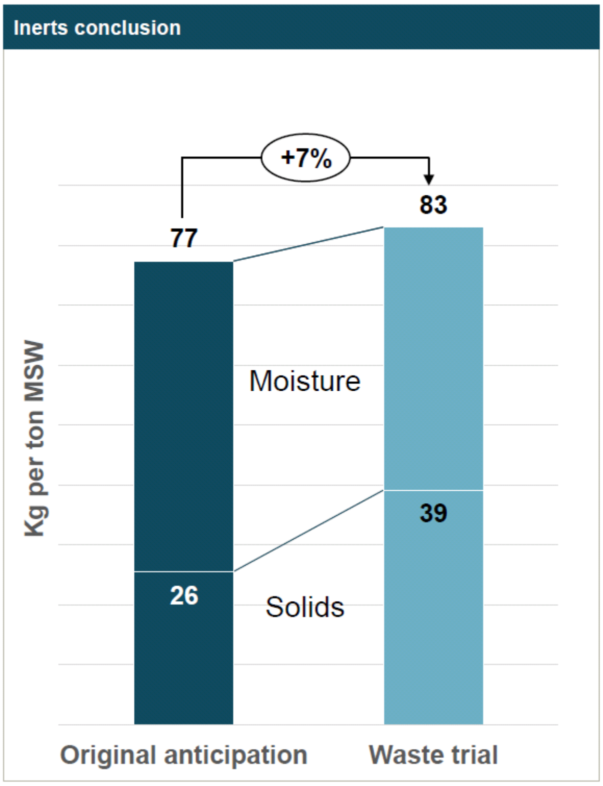


Figure 13 Average inert content in the output



The decrease of moisture in the output was related to improved separation of water during processing of this fraction in the pilot.

Figure 14 Average RDF content in the output

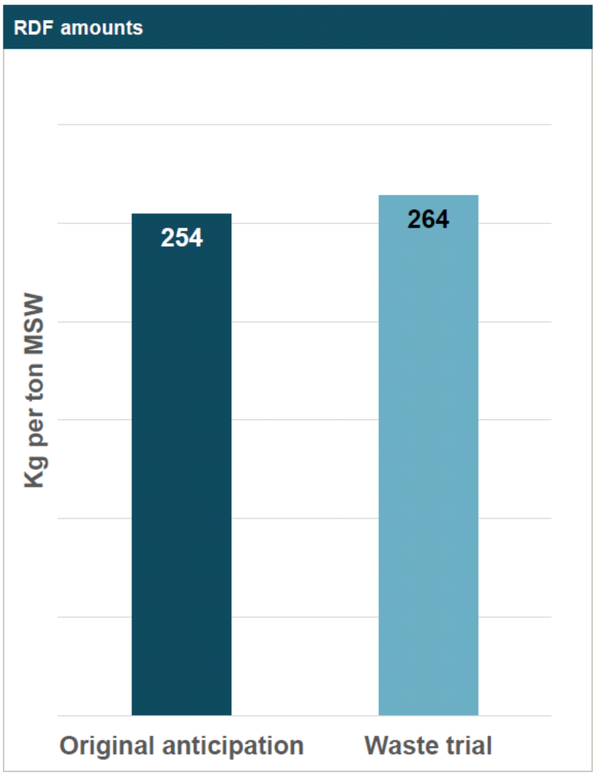
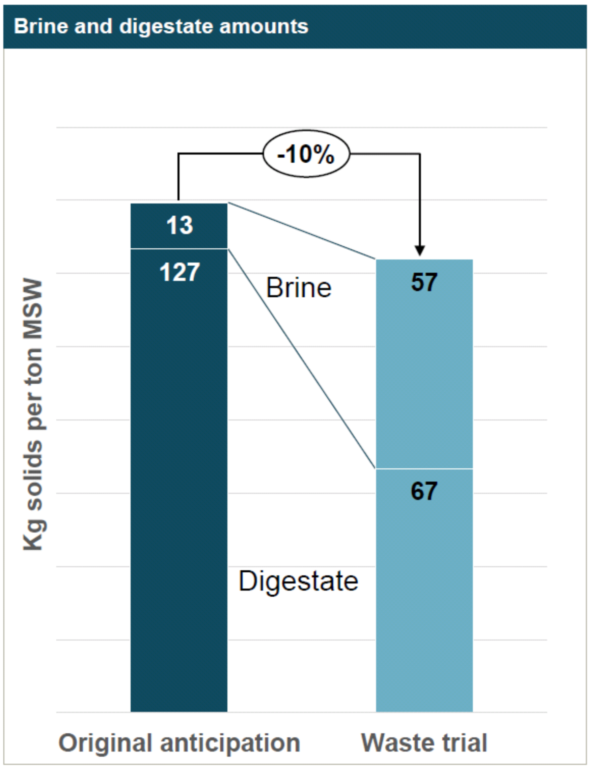


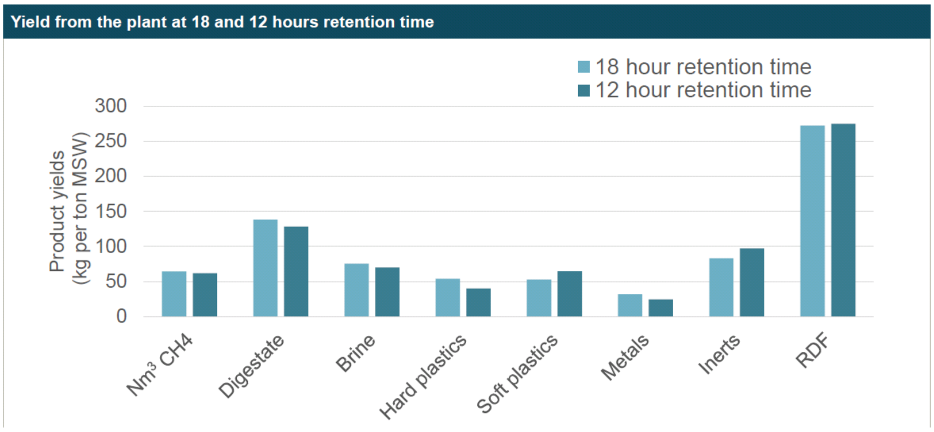
Figure 15 Average brine content in the output



3.4 Effect of retention time in the enzymatic reactor

Figure 16 shows the product output results for the two retention times applied in the enzymatic reactor.

Figure 16 **Product output streams at two retention times**



While no significant differences are found a first indication can be given that a retention time of 12 hours seems sufficient for this CURE waste composition. This result needs to be confirmed by more investigation and testing. If proven correct this will have a strong positive effect on the amount of waste to be processed per invested cost of CAPEX.

4 Conclusions

Based on the findings of the pilot plant tests on waste batches from apartments (‘hoogbouw’) provided by CURE showed the following conclusions are drawn:

1. The input batches provided by CURE showed about 31-47% less digestible biomass content than earlier expected by REnescience-Dong. However the mean plastic and metal content was about 20% higher.
   One batch showed too much deviation and was not representative.

2. Based on early analyses of pH and COD the operation of the reactor seems to have behaved stable over most of the test period. Apart from short stops, related to known incidents like a large brick and braids, these indicate that steady state has been reached. Definitive conclusions can exclusively be drawn from the analyses i.e. on biogas production of the bio-liquid and the mass fractions produced and can support the preliminary business case.

3. The gas potential from the resulting bio-liquid was 22% less than expected, but the plastic yield was 20% more. It is interesting to know how this affects the LCA. These will have opposite effects in the business case resulting in decreased effect on the overall result. This was confirmed by REnescience-Dong.

4. Even with the deviations in input the current findings give no reason for concern and the pilot plant operated well. However it is recommended that the actual waste composition of CURE is monitored in time by analyses including confirmation of the water content.

5. The next step is the upscaling based on the results obtained and refinement of the heat and mass balances and business cases.

Annex A Pictures of site visit

Pictures of the November 4th visit of the pilot plant tests with CURE waste.

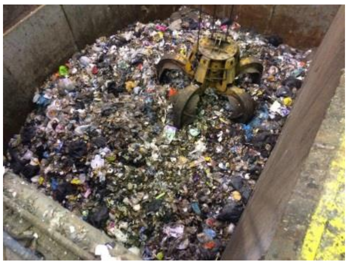
2D wash water fibres

Battery from Bioliquid sieve

Bra (2D)

Inert from bioliqued

Bunker with crane



Bunker

Dog toy (3D)

Drop bag from the 2D fraction

Infeeder

Knife from Bioliqued sieve

Large particles from Bioliquid sieve

Medicine bottle

Painting container (3D)

PET bottle (3D)

Plastic milk container (3D)

Shield from household machine (3D fraction)

Sink equipment bunker

Small gas container from Bioliquid sieve

Small piece of cerpentry from Bioliquid sieve

Washed 2D fraction

Washed 3D material

Weight for ME balance measurements

Wooden shoe from 3D fraction

2D wash bottom fraction