Final report

1.1 Project details

Project title	Releasing Energy Potentials from Yard Waste, Seaweed and Stream Weed Cutting via Aikan technology
Project identification (program abbrev. and file)	EUDP J.nr. 64015-0607
Name of the programme which has funded the project	Energiteknologisk Udviklings- og Demonstrations Program (EUDP)
Project managing company/institution (name and address)	Aikan A/S
Project partners	Aikan A/S
CVR (central business register)	29840997
Date for submission	13. February 2018

1.2 Short description of project objective and results

The naturally occurring surplus: fine fractions of yard waste, stream weed cutting and seaweed from beach cleaning is an unexploited source of energy. It was shown that Aikans 2 phase biogas and composting plant can extract this unexploited potential without problems caused by sand and salt from seaweed. The demonstration showed that seaweed from beach cleaning is random due to the municipal practices and priorities, and thus of small importance in the present showcase, whereas yard waste and stream weed cutting can contribute with a potential of up to 72 and 6 Nm^3 methane per ton fresh weight. The value chain shows that a precondition for harvesting these potentials is that the plant gets feedstock from other sources such as biodegradable municipal solid waste. The unification of materials in one place is rational and creates the needed economy to exploit the energy potentials.

1.2.1 Dansk beskrivelse

Den fine fraktion af haveaffald, samt grøde fra vandløb og søer og tang fra stranden er naturligt forekommende ressourcer, som udgør en uudnyttet kilde til energi. Det foreliggende projekt har vist, at Aikans 2-fase biogas- og komposteringsanlæg kan udtrække det uudnyttede energi potentiale, uden problemer med sand eller salt i tangen. Demonstrationen viste, at tang fra strandrengøring er meget sporadisk forekommende på grund af den fremherskende kommunale praksis og lave prioritering. Tang er således af mindre relevans, mens have-parkoverskud (HPO) og grøde kan bidrage med et potentiale på henholdsvis 72 og 6 Nm^3 metan pr. ton frisk vægt. En opstillet værdikæde viser, at det er en forudsætning for høst af dette potentiale, at anlægget får tilført andre råvarer, som f.eks. kildesorteret organisk dagrenovation (KOD). I en samlet løsning med KOD vil både potentialet i HPO og grøde kunne høstes på de eksisterende markedsbetingelser i Danmark.

1.3 Executive summary

The overall objective of this project, was to demonstrate that fine (fraction) yard waste (FYW), stream weed cuttings (SWC) and seaweed from beach cleaning (BC), could be handled and used as feedstock by Aikans 2-phased dry anaerobic digestion plant, BioVækst and that the value-chains of these feedstocks, environmentally and economically, would be improved when treated with the Aikan technology, due to the exploitation of an, until now, unexploited energy potential. The demonstration showed that all materials were easily handled. Neither sand nor salt content created any problems. The energy potential from all sources vary naturally as expected. Potential from BC can be expected to be between 2-30 Nm^3 methane per ton fresh weight. Potential from SWC can be expected 6 Nm^3 methane per ton fresh weight. Potential from FYW can be expected to 72 Nm^3 methane per ton fresh weight. To extract the full potential the retention time must be considerably longer than for easier degradable wastes as biodegradable municipal solid waste. FYW is the most stable and regular source for feedstock, whereas BC is rare because beach cleaning has a very low priority by the participating municipalities. FYW and SWC can realistically be exploited on plants treating other feedstock as the main source, whereas seaweed is to low ranking in the value chain. Aikan will pursue the FYW due to availability and methane potential, whereas BC and SWC will just be received whenever posing a problem for municipalities.

1.4 Project objectives

The objective of this project was to demonstrate that a currently unexploited energy potential of fine (fraction) yard waste (FYW), stream weed cuttings (SWC), and seaweed from beach cleaning (BC) could be utilized by Aikans robust 2-phased dry anaerobic digestion (AD) technology, to produce biogas (and subsequently electricity and heat) and quality compost. Thus, improving the value-chains of these feedstocks both environmentally and economically. The demonstrations were to be carried out at the Aikan plant, BioVækst, near Audebo (DK).

1.4.1 Work packages (WP)

The project was split in to 4 work packages designed to get around all corners of the project, from overall management, to execution of full-scale demonstration, as well as analysis' and evaluations. Within each WP a number of technical (M) and commercial (CM) milestones were decided upon (see Appendix 1: GANTT charge).

1.4.1.1 Project management (WP1)

Tasks – Securing that milestones were being reached; budget management; securing that legislation was followed; contact to staff and external partners (e.g. municipalities); Responsible for internal meetings and workshops with external participants; Communication with the public (e.g. through website).

Milestones – CM2: Homepage Launch; CM4: Public announcement; M4: Final report delivery.

1.4.1.2 Feedstock value chain (WP2)

Tasks – Mapping the value chains of feedstocks.

Milestones – CM1: Standardized value chain finished.

1.4.1.3 Full-scale demonstration at BioVækst (WP3)

Tasks – Feedstock characterization, e.g. determination of volatile solids, water content and Bio-methane-potential (BMP), of possible interesting feedstocks within the scope of the project; Evaluation of the feedstock characterization and preparation for full-scale; full-scale demonstration at BioVækst, with the feedstocks decided upon; Evaluation of gas-yields and compost quality from full-scale demonstrations; Evaluation of technical challenges related to the full-scale demonstration.

Milestones – M1: Feedstock characterized and ready for loading; M2 Results of first demonstration and feedstocks presented.

1.4.1.4 Technical improvements and utility model evaluation (WP4)

Tasks – Preparing the Aikan technology for the market of potential interesting feedstocks; Evaluation of patent possibilities.

Milestones – M3: Technological design finalized; CM4: Patent evaluation complete.

1.4.2 Implementation and obstacles

In general, Aikan is satisfied with the implementation of the project. Some objectives and milestones had to be modified slightly throughout the project, as new knowledge was obtained, or obstacles encountered. In the following the implementation of each WP is described.

1.4.2.1 Project management (WP1)

The internal project management proceeded without implications. Regular communication between the project manager and administration, the scientific staff and the operational staff ensured that the project proceeded smoothly. Operational meetings every 2-4 weeks allowed for a thorough planning of upcoming tasks. Operational obstacles were quickly dealt with, so that processes could be adapted.

Several Zealand municipalities (all of those from whom we could find a relevant contact information on technical staff), were invited to participate in a startup workshop on April 4th, 2016. The overall interest towards the project was good despite some municipalities not being able to participate. Staff from three closest municipalities (Holbæk, Odsherred and Kalundborg) participated in the workshop. The overall aim of the workshop was to identify the possible waste fractions, discuss the issues related to their handling and utilization, as well as to secure partners from whom we could receive the waste (feedstock) for the demonstrations.

The workshop was very constructive, with good inputs from the municipalities. Although neither Holbæk nor Kalundborg, did regular beach cleaning, the workshop made a good foundation for the further planning.

Website was created and managed by and external partner, with data provided by Aikan. The website was launched in accordance with milestones.

The final public announcement and demonstration day is yet to be planned, as the compost maturation from the last full-scale demonstration is not finished. It will be in early spring 2018 and announced via direct mail and on the project website.

1.4.2.2 Feedstock value chain (WP2)

The preparation of the feedstock value chain proceeded without implication. The assessment of the value chain was based on Aikans many years of experience with such work and knowledge about the market, combined with the results of the initial feedstock characterization, the first workshop and findings during the project.

1.4.2.3 Full-scale demonstration at BioVækst (WP3)

The characterization of feedstocks proceeded without any major complication. Feedstock characterization of BC was carried out both for individual (possible) components, i.e. the different types of marine algae and Eelgrass, as well as for actual BC. Feedstock characterization of SWC and FYW were only carried out for the actual waste.

The assessment of feedstocks resulted in some changes to the initial plan, as it was decided not to proceed with full-scale demonstration of BC waste. The reason being a combination of; lack of incentive to perform BC by the municipalities (see results workshop); the collected BC was driven to farmlands, where it was piled for composting. Aikan could collect the BC from the piles, but it was too degraded at the time of need; and low BMP (see results). The beach cleaning methods where analyzed though to evaluate costs and obstacles, information that could be feed into the value chain.

It was decided to run two main full-scale demonstrations, one with SWC (and FYW as structure) and one with just FYW. Further a control demonstration with BMSW was performed in between the two. A third run with FYW was cancelled due to lack of time within the project period. The beach cleaning methods where analyzed to evaluate costs and obstacles

During the first demonstration with SWC, the logging unit for percolate exchange between reactor and process module was out of order. This meant that some post-demonstration calculations were not possible. Percolate samples for chemical oxygen demand (COD) testing where taken every 2nd day, which allowed for better assessment of the demonstration (now that percolate flows could not be logged). COD samples were also taken during the BMSW demonstration for comparison purposes, but not during the FYW demonstration (the COD analysis is very time consuming), as all logging equipment were functioning properly.

The FYW demonstration proceeded as expected and no noteworthy issues were encountered.

Sample collection and analysis of compost quality was carried out by an external professional lab and proceeded without complication.

1.5 Project results and dissemination of results

1.5.1 Workshop with municipalities (WP1)

On April 4th, 2016, a startup workshop was held. Representatives from three municipalities, Holbæk, Kalundborg, and Odsherred were present. After a short presentation made by Aikan, a roundtable discussion was held. The workshop was mainly focused on BC and to some extend SWC, but not FYW since the collection and current handling was already known. The following main issues was discussed:

- What is the municipal strategy for BC?
    - Holbæk did not have a specific strategy and did not perform much beach cleaning, as they do not have many public beaches.
    - Kalundborg has decided not to perform beach cleaning (except under special conditions, e.g. after big storms).
    - Odsherred have many public beaches and many users of the beaches (mainly during summer) as they have a great amount of holiday housing in the region. Therefor BC is performed when needed. The BC is collected and driven to farmland, where it is left in piles for composting and spreading by the farmer.
- Concerns regarding the amount of heavy metals (cadmium specifically mentioned) in the BC and SWC were raised. Aikan did not expect the heavy metal concentration to be too high, although the concentration would vary depending on the degradation of the waste. Heavy metal concentrations in the final compost from demonstrations would be measured.
- Handling obstacles when treating BC and SWC
    - Sand handling, e.g. can the process handle it, or does it need to be removed – Aikan would test this.
    - The need for shredding – Aikan believed that this was probably not necessary.
    - Need for washing to remove salt – Probably not a problem, but it would be tested.
- Could there be unknown advantages related to the mixing of fore example FYW and BC, e.g. enzymes or microorganisms that could enhances processes – Aikan would look into that.

1.5.2 Feedstock value chain (WP2)

Today the cheapest solution is direct spreading on land or leaving the materials unrecovered on beaches or banks. The feasibility of the Aikan plant is built upon: gate fees, energy sales and the value of the compost. To cover initial investment costs the feedstock supply must be stable and available in a big scale, which is not the case for SWC and BC. However, in combination with BMSW a business case can be realistic. A general example of key-figures in such a business case is given in annex 2. Different feedstock value chains with and without the Aikan treatment can also be found in annex 2. The initial consideration about feedstock value chains can be found in annex 3.

For all feedstock, the Aikan technology adds energy recovery to the value chain, which results in reduced release of CO_2 emission and less CH_4 from composting. Aikan also adds a more efficient balance to the value change due to the exploitation of unexploited resources (methane). Thus, the exploitation of YW and SWC can be carried out on the present market conditions on an existing Aikan plant (see also: 1.5.7 Economic prospects of treating FYW and SWC).

1.5.3 Feedstock characterization and assessment

At the early stages and throughout the project period characterization of feedstocks where carried out, by determining water content, dry matter (total solids, TS), organic matter (Volatile Solids, VS) and biomethane potential (BMP). The results are shown in Table 1 and Table 2:

Table 1: Water content, Total Solids (TS), Volatile Solids (VS) of different feedstocks (as percentage of fresh weight, FW, as well as percentage of TS for VS).

Water content, Total Solids, Volatile Solids				
Substrate:	***Water content (% of FW)***	***Total Solids (% of FW)***	***Volatile Solids (% of FW)***	***Volatile Solids (% of TS)***
Eelgrass	**82,7**	**17,3**	**10,2**	**59,2**
Ulva (Green algae)	**80,7**	**19,3**	**13,4**	**69,3**
Bladderwrack (brown algae)	**78,3**	**21,7**	**16,5**	**75,8**
Gutweed (Green algae)	**94,8**	**5,2**	**2,2**	**41,6**
Stream Weed Cuttings**	**90,7**	**9,3**	**6,2**	**66,7**
Fine fraction of yard waste	**40,7**	**59,3**	**40,2**	**67,7**

**Mixture of Eel grass, Bladderwrack, different waste, sand and a.o.*

***From Lammefjordskanalerne, mixture of aquatic and riparian vegetation.*

Table 2: Bio-methane-potential, BMP, of the different feedstocks tested in this project. The cellulose value is a control value that indicates how efficiently the used percolate utilizes the organic matter in the feedstock.

BMP (m3 CH_4/tonVS)					
Substrate	***nov-15***	***jun-16***	***jul-16***	***aug-16***	***sep-16***
Eel grass	**155.5**	**-**	**-**	**-**	**-**
Ulva (Green algae)	**230.6**	**235.0**	**-**	**-**	**-**
Bladderwrack (brown algae)	**62.9**	**129.0**	**-**	**-**	**-**
Beach cleaning*	**-**	**-**	**138.5**	**-**	**-**
Gutweed (Green algae)	**-**	**-**	**-**	**109.2**	**-**
Stream Weed Cuttings**	**-**	**-**	**-**	**-**	**100.5**
Fine fraction of yard waste	**-**	**-**	**178.8**	**-**	**-**
Cellulose (control)	**380.3**	**337.1**	**339.4**	**320.0**	**357.0**

**Mixture of Eel grass, Bladderwrack, different waste and sand.*
***From Lammefjordskanalerne, mixture of aquatic and riparian vegetation.*

The normal feedstock at BioVækst is, as mentioned earlier, Biodegradable municipal solid waste (BMSW). Normally BMSW has a water content of around 70 % and hence around 30 % dry matter (total solids), with a VS content usually between 80-90 %. The BMP of BMSW is normally between 350-400 m^3CH_4/tonVS (but can range from 300-450).

The BMP values of the different feedstocks that was tested in this project ranged from around 25-50 % of those of BMSW. A similarly lower gas output would be expected when running full-scale experiments, if equal amounts of VS were added to the process. Although, as feedstocks are added in fresh form to the process, water contents and VS:TS (or VS:FW) ratios will also be determining for the gas output. In general, feedstock (FW) with a low water content and a high VS:TS ratio will yield more gas than the opposite, although it should be noted that not all VS can be turned in to gas (e.g. plastic is also VS). This relation is easier to see if BMP is calculated per ton of fresh feedstocks (FW-BMP), as done in Table 3.

Table 3: Bio-methane-potential of Fresh weight feedstock, FW-BMP, of the different feedstocks tested in this project.

FW-BMP (m3CH_4/tonFW)	
Substrate	***FW-BMP***
Eel grass	**15,9**
Ulva (Green algae)	**30,8**
Bladderwrack (brown algae)	**10,3**
Gutweed (Green algae)	**2,4**
Stream Weed Cuttings*	**6,2**
Fine fraction of yard waste	**71,8**
BMSW**	**100 (up to 120)**

**From Lammefjordskanalerne, mixture of aquatic and riparian vegetation.*
***BMSW from different municipalities received by BioVækst.*

Due to the relatively low water content of FYW, it can be seen (Table 3) this feedstock has a FW-BMP of just over 70% of that of BMSW. If just looking at the standard BMP (m^3CH_4/tonVS) FYW had less than 50% of that of BMSW.

Contrary to that of FYW all the other feedstocks had a reduced potential (compared to BMSW) when accounting for water content and VS:TS ratio.

Even though none of the tested feedstocks compared to BMSW on BMP/FW-BMP, these feedstocks are overall considered relatively clean (i.e. mostly degradable organic material) and the amount of residual waste (expense) coming from these will probably be somewhat lower than the amount coming from BMSW (15-30 % of FW), why the lower BMP values may not necessarily mean that the different feedstocks could not be utilized profitably.

As mentioned only SWC and FYW were considered for full-scale analysis and due to its easy accessibility, relatively high FW-BMP and low rate of impurities FYW were the immediately most promising feedstock of the tested feedstocks.

1.5.4 The effect of salt on BMP

An extra BMP measurement of fresh bladderwrack were run, to test for possible effects of salt coming from marine feedstock. Unwashed and washed (with freshwater) bladderwrack was tested. No significant difference between the two could be seen (the unwashed was slightly higher).

1.5.5 Full-scale demonstration

1.5.5.1 Setup and Biogas-production

As it was decided not to use beach cleaning waste for further analysis (see earlier), only FYW and SWC were used for full-scale demonstration. The first demonstration was conducted from October-November 2016 and the feedstock for this demonstration was SWC (with FYW as structure). The second demonstration was conducted September-November 2017 with FYW as the feedstock. Results can be seen in Table 4, Figure 1.

As mentioned, during the SWC demonstration the logging unit of percolate transported between module and reactor was out of order. Therefor a total m^3 of moved percolate, as well as Biogas per m^3 percolate value could not be obtained. Total m^3 of moved percolate is expected to have been in the same region as for BMSW and FYW (2000-3000 m^3).

From years of experience at BioVækst, it has been found that the optimal retention-time (at BioVækst) of BMSW in the biogas-phase is approximately 21 days (past this point the gas-production is <u>usually</u> reduced and keeping it in the gas-phase is not feasible). Other feedstocks may have different optimal retention-times, dependent on the composition of the feedstock, hence why the demonstrations of SWC and FYW were kept in the gas-phase for extended periods, 40 and 55 days respectively (see Table 4 and Figure 1).

Table 4: Data and calculations obtained from full-scale demonstrations at BioVækst, of biodegradable-municipal-solid-waste (BMSW), stream-weed-cuttings (SWC), and fine-yard-waste (FYW).

Full-scale demonstration			
	BMSW	**SWC**	**FYW**
Total Biogas (m^3)	**8145**	**3397**	**8601**
Process days	**25**	**40**	**55**
Amount of Feedstock (estimated, ton)	**110,0**	**110,0**	**110,0**
Percolate to reactor (m^3)	**2973**	**-**	**2541**
Biogas pr. Ton (m^3)	**74,0**	**30,9**	**78,2**
Biogas pr. m3 percolate	**2,7**	**-**	**3,4**
Gas pr. Day	**325,8**	**84,9**	**156,4**

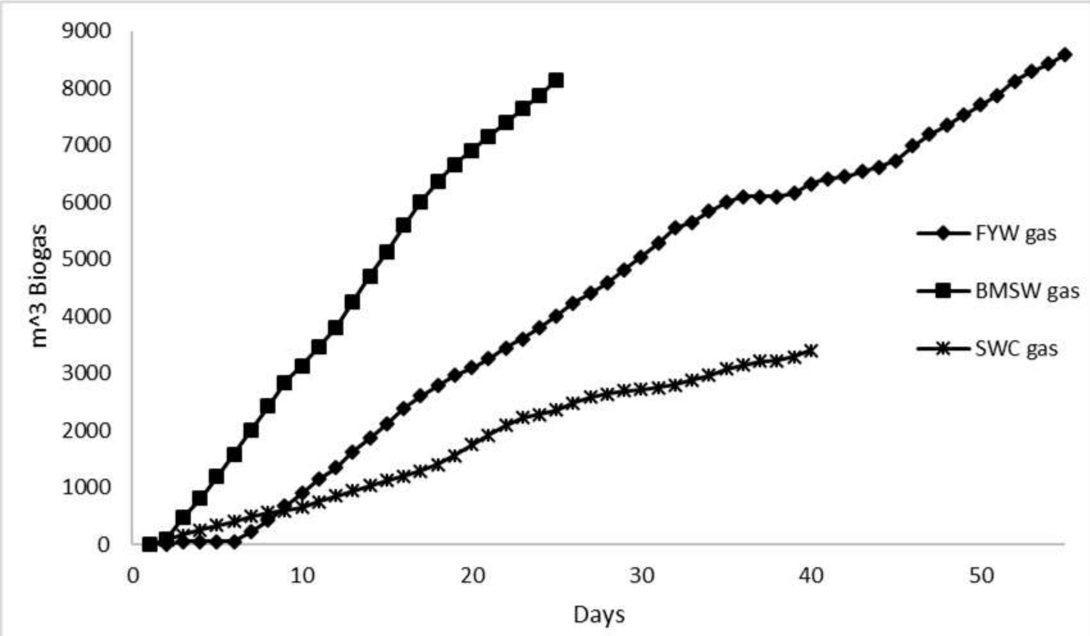


Figure 1: Biogas production (accumulated) from full-scale demonstrations at BioVækst.

As the biogas-phase of the BMSW demonstration was 25 days, comparison of biogas-yields at the 25-day mark of the FYW, SWC and BMSW demonstrations makes good sense, especially because, a biogas-phase of 25 days is in accordance with normal procedure at BioVækst. The biogas-production at the 25-day mark was 8145 m^3 for BMSW, 4014 m^3 for FYW, and 2359 m^3 for SWC. Compared to BMSW, FYW and SWC produced approximately 50 % and 30 % respectively, which is quite close to what would have been expected from the BMP-analysis.

In neither of the three demonstrations gas-production had stalled at the end of the gas-phase, thus a higher gas-yield could have been obtained. In practice though, keeping the feedstock in the gas-phase for extended periods would rarely be economically interesting (will be discussed later).

Due to the extended biogas-phase the biogas-yield of FYW (Table 4) surpassed that of BMSW (Table 4). This may not be surprising as the biogas-phase was more than twice as long. Although, as the biogas-production of BMSW often starts to decrease within the first 30 days, the biogas-yield of the BMSW demonstration, would probably not have reached twice the volume of the FYW biogas-yield (as seen after 25 days). It seems possible that the biogas-yields would have proportionally resembled the results of FW-BMP calculation (e.g. FYW-yield around 70 % of the BMSW-yield). In any way, it is interesting that the biogas-production from FYW was relatively stable throughout the demonstration (i.e. did not stall) and that a biogas-yield similar to that of normal BMSW procedure could be obtained, although at the cost of an extended retention-time.

1.5.5.2 COD of SWC and BMSW

As mentioned earlier the SWC and FYW gas-phases was extended compared to BMSW, which results slightly different percolate circulation. Therefor the COD values of SWC and BMSW cannot be compared 1 to 1 at the individual days. But as seen the maximum value of BMSW is approximately 3.5 times larger than the SWC maximum value, which is in line with the results obtained from the BMP analysis and seem to fit well with the total gas production.

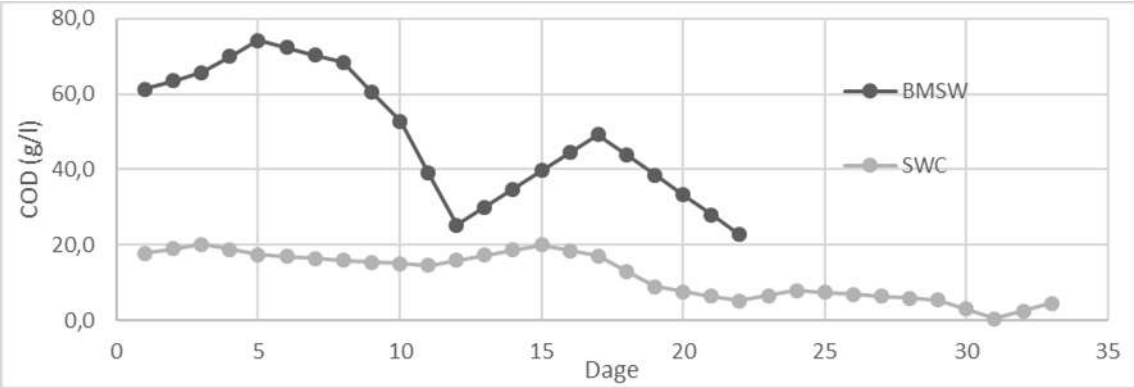


Figure 2: COD SWC and BMSW. COD values are calculated as COD of process module percolate minus COD of reactor tank percolate.

1.5.5.3 Handling and processing FYW and SWC (and BC)

As the process at BioVækst already today includes the coarse fraction of yard-waste, handling the FYW was not associated with any implication. The SWC from Lammefjordskanalerne was more compact than the FYW, but besides that the structure was comparable, and handling of the fresh material did not cause any problems.

Although both FYW and SWC are considered relatively clean feedstocks the compost-analysis of SWC showed a high content of rocks larger than 5mm (Table 5). This does not necessarily posse a problem as most rocks can be separated by a stone trap at the sorting facility at BioVækst. Although, because the SWC compost were quite sticky, the compost and stones were clinging together, which did either result in too much of the compost being removed or too little of rocks being removed when sorting it. The SWC had not being actively aerated during maturation, which would have resulted in a dryer compost. The separation of rocks and compost would have probably been easier if the compost had been aerated.

Further, the rocks are not expected to have originated from the SWC itself. When SWC from Lammefjordskanalerne has been cut, it passively drifts to a collection-station where it is grabbed off from the surface, hence making it unlikely to contain many (if any) rocks. Some rocks could have been picked up during loading of the truck (taking it to BioVækst) as the SWC had been stored on the soil. Although, the most likely scenario is probably that the rocks come from the FYW (structure material in the SWC demonstration). BioVækst receive YW from the neighbouring resource-centre, where the YW is stored on gravel. If the frontend-loaders are not careful, when loading the YW, they can pick up a lot gravel and thus contaminate the YW (which unfortunately often happens).

Although no full-scale demonstration with BC was performed, Aikan is still confident that handling and processing will not cause any problems.

1.5.5.4 Compost-analysis (SWC)

A sample of the maturated compost from the full-scale demonstration of SWC were collected by Eurofins and analysed. The full report can be found in Annex 4. A reduced (and translated) version can be seen below (Table 5).

Table 5: Key-results (selected by Aikan A/S) of the compost-analysis performed by Eurofins A/S on behalf of Aikan A/S. Translated to English by Aikan A/S.

Compost-analysis (reduced version)		
Component	**Result**	**Unit**
pH	7.8	pH
Dry matter	51	%
Density	0.6	g/cm³
Solvita compost test	4	color unit
Stability	Very stable	-
Particles < 2 mm	27	% TS
Particles < 5 mm	62.1	% TS
Rocks > 5 mm	33.3	% TS
Plastic > 2 mm	0	% TS
Metal > 2 mm	0	% TS
Glass > 2 mm	0	% TS
Nitrogen, total	7700	mg/kg
Phosphor, total	2700	mg/kg TS
TOC, total organic carbon	160000	mg/kg TS
TOC/TN	11	-
Arsenic (As)	< 2	mg/kg TS
Lead (Pb)	12	mg/kg TS
Cadmium (Cd)	0.36	mg/kg TS
Chromium (Cr)	28	mg/kg TS
Copper (Cu)	34	mg/kg TS
Mercury (Hg)	0.043	mg/kg TS
Zink (Zn)	130	mg/kg TS
Nickel (Ni)	7.7	mg/kg TS

The SWC compost was found to be very stable, with low levels of heavy metals. In fact, heavy metal levels are well within the limits (Table 6) for use in both conventional and organic agricultures.

Table 6: Heavy metal limits for compost use in conventional and organic agricultures.

	Conventional limits (mg/kg TS)	Organic limits (mg/kg TS)
Cd	0,8	0,7
Pb	120	45
Hg	0,8	0,4
Ni	30	25
As	25	-
Cr	100	70
Zn	4000	200
Cu	1000	70

No plastic or glass (>2mm) was found in the compost. The compost had a very high level of rocks (>5mm), but as mentioned earlier the rocks is suspected to have originated either from the pickup location or (more likely) from the YW (see explanation in 1.5.5.2).

Compared to the normal BMSW compost, the SWC looked rather similar with regard to pH and dry matter (maybe slightly lower than the average BMSW compost), whereas nitrogen and phosphor levels were significantly lower than average BMSW values (they can vary a lot), which of course means less nutrients. On the other hand a mix of BMSW and SWC might give an optimal nutritional value.

Based on the compost analysis, Aikan expect that the SWC compost will have good soil improving properties, as well as reasonable fertilizing properties.

The SWC was performed in spring, autumn SWC would possibly show different values.

1.5.6 Adapting the Aikan technology to FYW and SWC treatment (technical considerations)

Both FYW and SWC are distinctively different than BMSW and if Aikan (BioVækst) was to handle these waste streams commercially a few minor adjustments to handling and process would be in place.

1.5.6.1 Receiving area

A separate receiving area must be dedicated for the FYW and SWC, as neither FYW nor SWC contain noteworthy impurities and hence does not need the same pre-treatment as BMSW (i.e. bag opening and separation). Contamination from BMSW would also be avoided. Further, a separate receiving area would allow the potentially wet SWC to be drained before it was loaded for process.

1.5.6.2 Process adaptation

FYW and SWC are quite homogeneous feedstocks and they do not contain as much easily accessible organic matter as BMSW do, therefor hydrolyzation is slower and gas-output (pr. time unit) lower. Both FYW and SWC showed a steady gas-output throughout their respective demonstrations, which suggest that a longer gas-phase for these feedstocks would be ideal. A longer gas-phase for BMSW is not ideal (see below), which means that the two processes should optimally be run as separate batches. Keeping part of the plant (process modules, maturation bays and compost storage area) dedicated for FYW/SWC would also prevent contamination from the BMSW to enter the FYW/SWC compost, which would give Aikan the opportunity to produce a clean compost product suited for organic agriculture.

1.5.7 Patentability

Since no major technical changes was really needed, patentability was considered of no relevance since Aikan technology itself is already patent protected.

1.5.8 Economic prospects of treating FYW and SWC

Most (around 60 %) of the income from BMSW comes from the gate-fee Aikan (BioVækst) receive. This means, that from a strictly economical point of view it is better to receive more waste than it is to obtain the full gas-potential of the waste. From an environmental point of view, it is of course better to recover as much of the energy (methane) as possible. Considering both aspects are important for Aikan, as the Aikan concept is built around the production of green energy (and quality compost). As mentioned earlier, the Aikan process has a gas-phase of around 21 days for BMSW, which is approximately the time, that it takes to convert the easily degradable organic matter in to biogas. Once the biogas-production slows down, the income difference between receiving new waste (i.e. gate-fee) versus continued gas-production becomes larger and the environmental gain becomes smaller, hence why this is not feasible. In theory, the same dynamics apply for FYW and SWC (and BC), but as they have different feedstock characteristics than BMSW and their gate-fees will be lower, the business case will look somewhat different.

1.5.8.1 FYW and SWC business case considerations

Normal gate-fees for YW is in the region of 100-200 DKK pr. ton, which is around 1/2 to 1/3 of the gate-fee of BMSW. Alone for this reason, receiving BMSW will be a more prosperous business than receiving FYW and SWC. On top, BMSW also has a higher BMP than the others.

The advantage of FYW and SWC is that it is clean, BMSW contains 7-25 % of impurities, which need to be separated and transported to incineration at a cost of around 400-450 DKK pr. ton.

Due to the current extremely varying handling practices of SWC, that range from simply leaving it on the bank to treating it similarly to YW, it is uncertain whether Aikan will be able to charge a gate-fee for it. Most SWC will be comparable to FYW and hence a gate-fee in the region YW or slightly lower should be a reasonable charge. Without gate-fee receiving the SWC, would most likely not create any revenue for Aikan, but only be of environmental character.

In the following, Aikan considers a few possible scenarios by which BioVækst, as showcase, could make a profitable business out of treating FYW and SWC. The considerations reside on the assumption that there is available capacity at the plant (i.e. at full capacity, BMSW will always be the more prosperous feedstock):

1. BioVækst receive the FYW from Solum Roskilde (SR) or ARGO, i.e. They receive the YW and gate-fee as usual, while BioVækst then receive the FYW for a fee equal to the normal expense of dispatching the FYW. In this way Aikan/BioVækst would not have to find new sources of YW (which they would have to compete for) and ARGO or SR would see their waste treated environmentally better, than it is today, without any extra expenses. The receiving-fee would be low and gas-output and income from compost, would be of higher economic importance than for BMSW. SWC would be received with or without gate-fee directly by BioVækst.

   As both SWC amounts and the quality of FYW is seasonally depend (i.e. SWC is performed mainly in spring and late summer, while FYW is of better quality, when rich on foliage during spring, summer and early autumn) running dedicated FYW/SWC batches would only be carried out seasonally. Off season, FYW and SWC (if received) would only supplement the normal BMSW batches (to fill the capacity). Dedicated FYW and SWC batches should have and extended gas-phase (if not obstructing normal processing of BMSW), to enhance the revenue from gas-production.

2. Generally, the BioVækst showcase and value chains, tells that the synergy lies in logistics and local conditions. The surplus from beaches (BC), streams (SWC) and gardens and parks (FYW) all must be collected due to public needs. An Aikan plant based on other continued feedstock such as BMSW (or manure, slurry, sludge etc.) must be in place. In that case the natural occurring resources can provide an extra biogas output and source of nutrients, especially interesting in organic farming due to the very clean compost.

1.5.9 Realization of objectives

Aikan have managed to show that both FYW, SWC and SW can be handled satisfactory by the Aikan technology and that the feedstocks can be supplementary to other feedstocks thus enhancing the flexibility of the Aikan technology. All objectives and milestones have been achieved.

1.5.10 Dissemination of results

The Webpage is used as communication platform. The report and findings are communicated via this channel, but interesting parties are told by direct mail about the existence.
Invited municipalities are informed by directs mail about the report on the webpage too.
The present report is in English, since it will be used for Aikans foreign customers, as well as in Denmark.

1.6 Utilization of project results

The results of the project feeds directly into the strategy for Aikan to be a global supplier of AD technology. The findings show which role the feedstocks can play in a future plant and what obstacles that must be overcome. BioVækst, as a showcase, reveals important aspects of the value chain and motivation by interesting parties. The concrete energy outputs show what level of gate fee that is needed to make a viable business case.

1.7 Project conclusion and perspective

The project has demonstrated that the Aikan technology is capable to utilize both the fine fraction of yard waste (FYW), seaweed (SW) and stream weed cuttings (SWC) gaining energy recovery and CO_2 savings. The potential energy harvest is 72 Nm^3 methane per ton fresh weight FYW, 2-31 Nm^3 methane per ton fresh weight SW and 6 Nm^3 methane per ton fresh weight SWC. The concrete yields can be obtained by sufficient retention times. The marine feedstocks need to be fresh, which subsequently also mean high water contents leading to the relative low methane potentials per ton fresh weight. Salt and sand did not create problems neither in handling nor for the final compost product. Large quantities of sand can simply be screened of before treatment. The compost was suitable even within organic farming that have more strict limit values. The concrete availability of seaweed is limited since many municipalities do not do beach cleaning (BC) and the beach cleaning is too expensive to carry out just for the sake of the energy yields. SWC is available seasonally and will often be mixed with grass clippings from banks. The plant gate fee must be lower than land spreading costs, which is possible as soon as transportation costs is involved. FYW is available as a reliable source and the gate fee together with the energy yields represent a viable business case together with other feedstocks like biodegradable municipal solid waste. It was within the project period not possible to determine the variability of the FYW, but it is expected that energy potential is less in the winter period. In large scale Aikan can handle YW and BMSW simultaneously adding BC and SWC, when available. The full energy yields from these materials can be obtained by unifying the treatment of masses in one place. Compost from the feedstocks is of high quality and can be used in organic farming, where there is a strong need for fertilizers. The project points to a strategy where municipalities do not just think of one organic resource each at a time but consider complete solutions to get as much renewable energy as possible. Aikan will be using the findings and demonstrations to market complete, sustainable solutions for multiple feedstocks and a variation of combinations.

Annex
Annex 1: GANTT charge
Annex 2: Feedstock Value Change
Annex 3: Value Change considerations
Annex 4: Compost Analysis of SWC compost

Links for continuous dissemination
www.aquaplantpower.dk

Gantt diagram

BEMÆRK: FILEN INDEHOLDER TO FANER

Project title: Releasing Energy Potentials from Yard Waste, Seaweed and Stream Weed Cutting via Aikan technology
Project start: January 2016

År	2016												2017												2018												2019											
Work packages/Projektets arbejdspakker:	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1. Project management																																																
Projectgroup meetings																																																
Workshops with external																																																
Statusreport																																																
Final report																								M 4																								
Communication (www=homepage, DD= demonstration day)								www	CM2									DD																														
Public announcements																								CM4																								
2. Feedstock value chain																																																
Maping incentives, logistics and economy of feedstock																																																
Strategy for biowaste feeding																																																
Standardized value chain						CM1																																										
3. Full-scale demonstration at Biovækst																																																
Feedstock characteristics																																																
Methane potential monitoring																																																
Mechanical separation of sand																																																
Washing of salty feedstock																																																
Fullscale demonstrations							M1											M2																														
4. Technical improvements and utility model evaluation																																																
Evluating sand/particle performance																																																
Evaluating salt accumulation																																																
Evaluating patent potentials																				M 3		CM3																										
Milestones/Milepæle																																																
M1: Feedstock characterized and ready for loading																																																
M2: Results of first demonstration and feedstocks																																																
M3: Technological design finalised																																																
M4: Final report																																																
Commercial milestones/Kommerc. milepæle																																																
CM1: standard valuechain finalized																																																
CM2: homepage launched																																																
CM3: patent evaluation complete																																																
CM4: technology introduction (marketing ready)																																																

Vejledning: Se dokumentet Vejledning/ please see Guidelines.

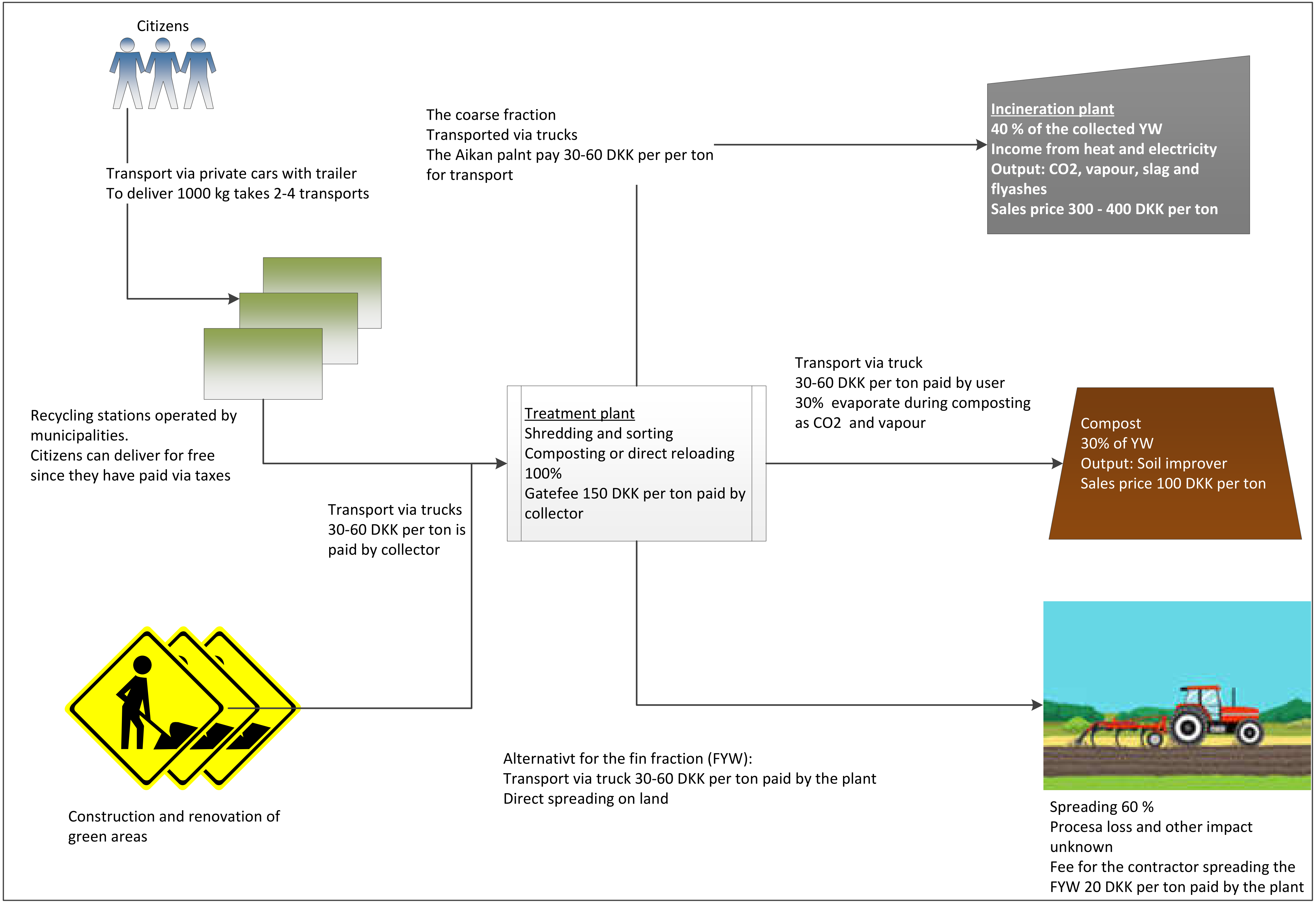
Dette skema er forberedt til op til 10 milepæle i alt. Flere kan tilføjes hvis nødvendigt./ This form is prepared for 10 milestones. If nescessary, further may be added

.

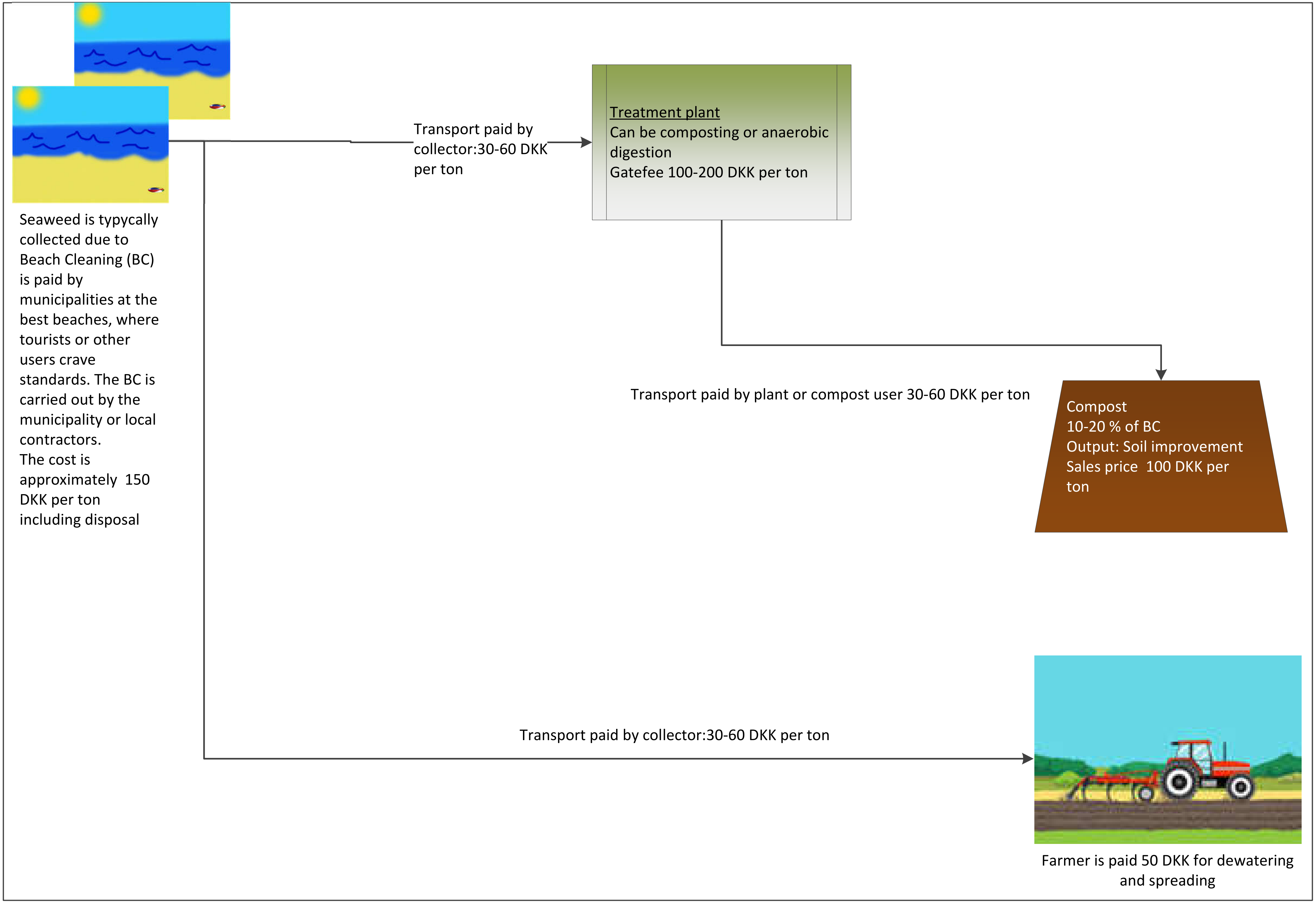
Project budget related to work packages (mio. DKK)

	TOTAL W.P.	Aikan
Workpackage no.1	0,73	0,73
Workpackage no.2	0,25	0,25
Workpackage no.3	1,7	1,7
Workpackage no.4	0,4	0,4
TOTAL PROJECT	**3,08**	**3,08**

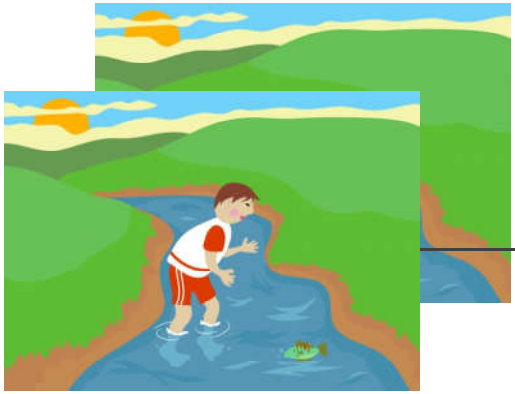
Yard Waste (YW) today



Seaweed (SW) as handled today



Stream Weed Cutting (SWC) today



SWC cut by owners or contractors who are paid to do this.
SWC is often mixed with bank cuttings (grass/herbs)
Where possible it is left on the bank otherwise it has to be transported away

Transportation is paid by owners 30-60 DKK per ton

Different arrangements of direct use as land spreading

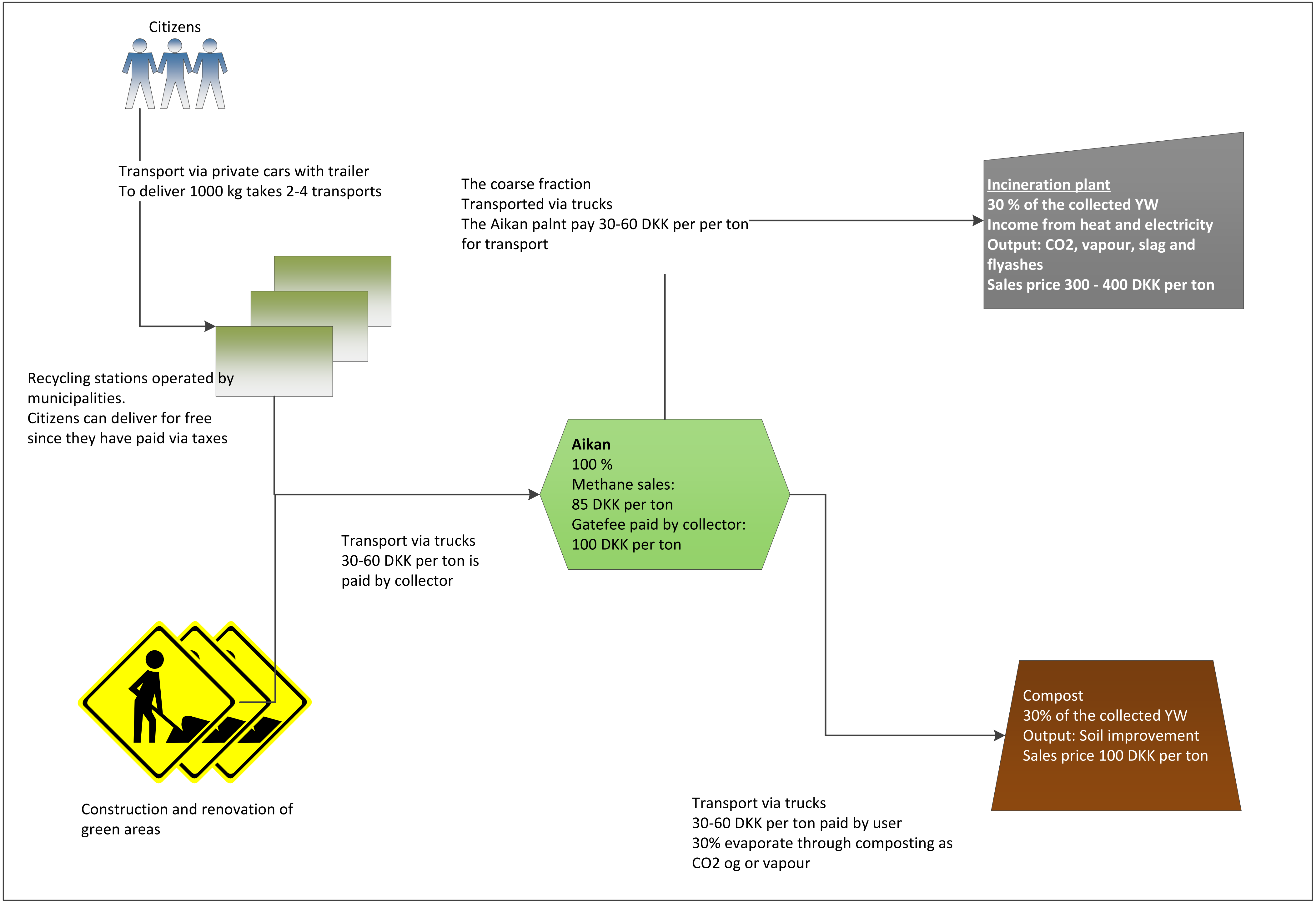
Transportation is paid by owners 30-60 DKK per ton

<u>Treatment plant</u>
Primaryly composting or dewatering since SWC contains a lot of water Gatefees 50- 150 DKK per ton

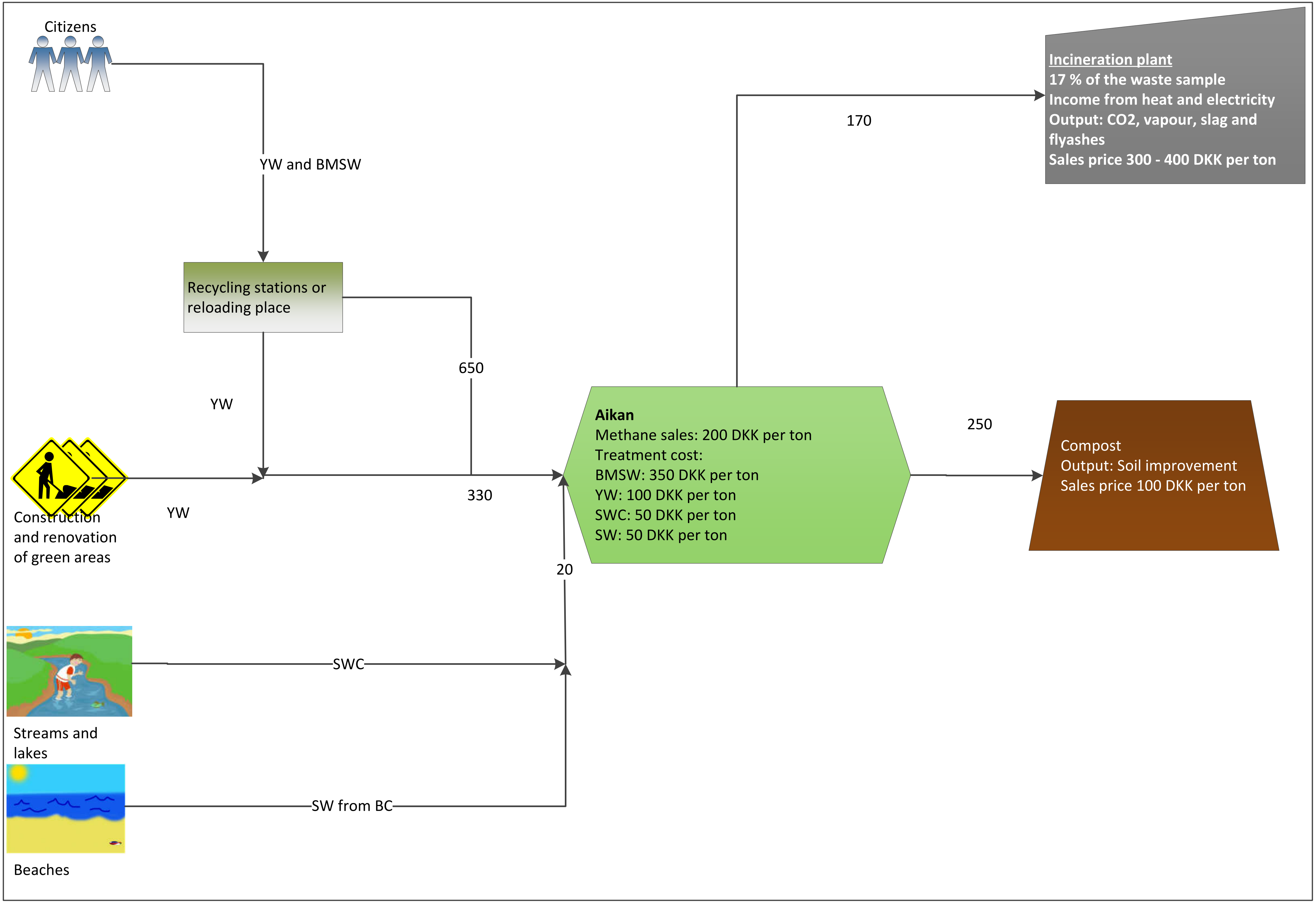
Transport cost
30-60 DKK per ton paid by plant or compost customer

Compost
10 % til 20 % of SWC
Output: Soil improvement
Sales 100 DKK per ton

Yard Waste (YW)



Example of business case



Draft Value Chain

Considerations for Yard waste, Seaweed and Stream Weed Cutting exploited via Aikan Technology

All wastes represent by definition costs for someone, which also mean that someone else gets income by transporting, handling or disposing etc. of these wastes. The idea of the present project is to decrease the costs without increasing the income by adding value to the waste types and thus gain value for society as a whole. At the same time resources should be exploited in a more efficient way.

Yard waste (YW) is created by public and private enterprises during maintenance or new construction works. YW are typically collected and transported in containers by private or public haulers, who bring the waste to a treatment facility – often a composting plant. The waste is being crushed and separated in two fractions. The coarse fraction is used for fuel and transported to a power or incineration plant. The fine fraction is composted and sold as a product often mixed with sand, peat or soil. The compost is transported by private haulers and bought by construction entrepreneurs or landscapers. The fine fraction might also be driven directly out on agricultural land without processing. The logistics is shown in figure 1.

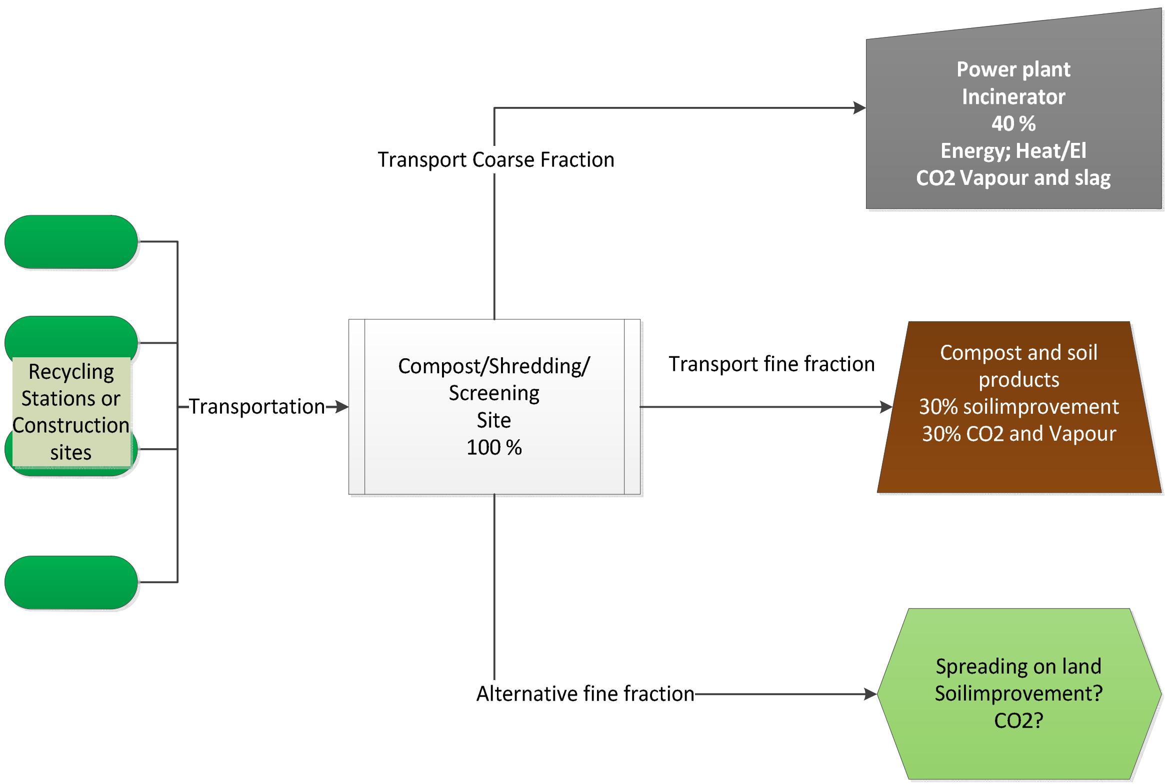


Figure 1: logistics today

The treatment cost for Compost/Shredding and Screening is 100-200 DKK per ton of YW. The cost cover manpower and machinery and the plant have revenue from fuel to the power plant and compost. The alternative route is used by haulers who have no cost for sites and pay farmers to store the fine material, but the solution creates environmental problems with smell and release of methane from piles with no ventilation.

The need for machinery and manpower could be solved by merging the pretreatment and Aikan since and Aikan plant would already own machinery and manpower. Thus the output will be more energy and compost as illustrated in figure 2.

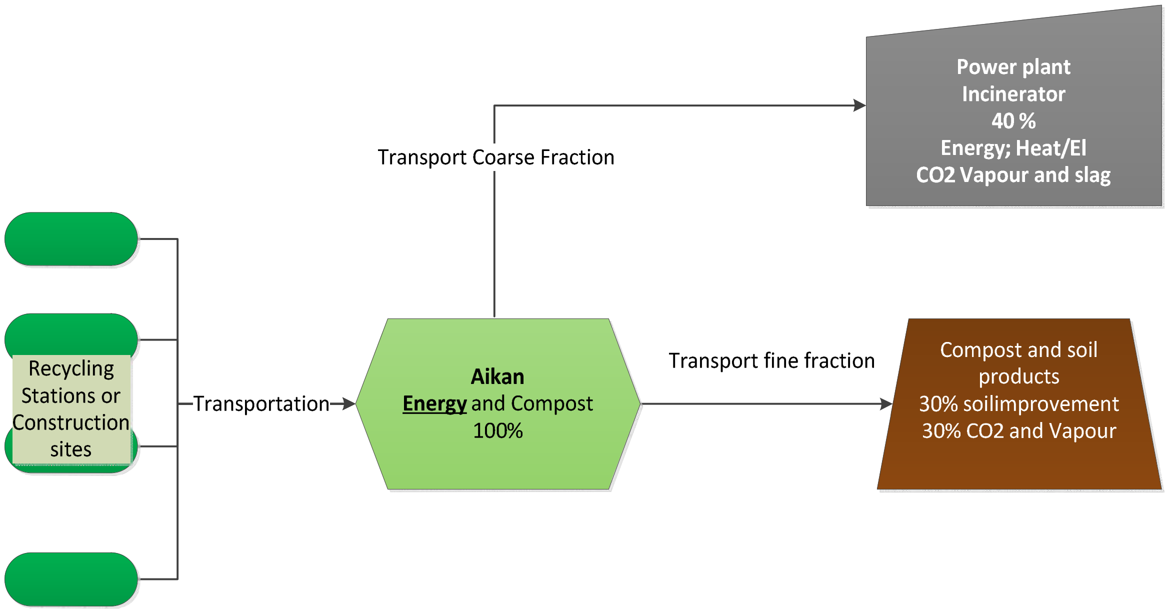


Figure 2: Logistics with an optimized Aikan solution

The treatment cost for BMSW at Aikan today is 350-400 DKK, but structure material is a cost. Thus if the fine fraction of YW can be used gaining energy, the treatment cost can be fully competitive even with a much better environmental performance.

Seaweed and SWC have a similar logistic as shown in figures 3 and 4. The water content of these materials varies very much. Thus dry matter can be from 10% to 90%.

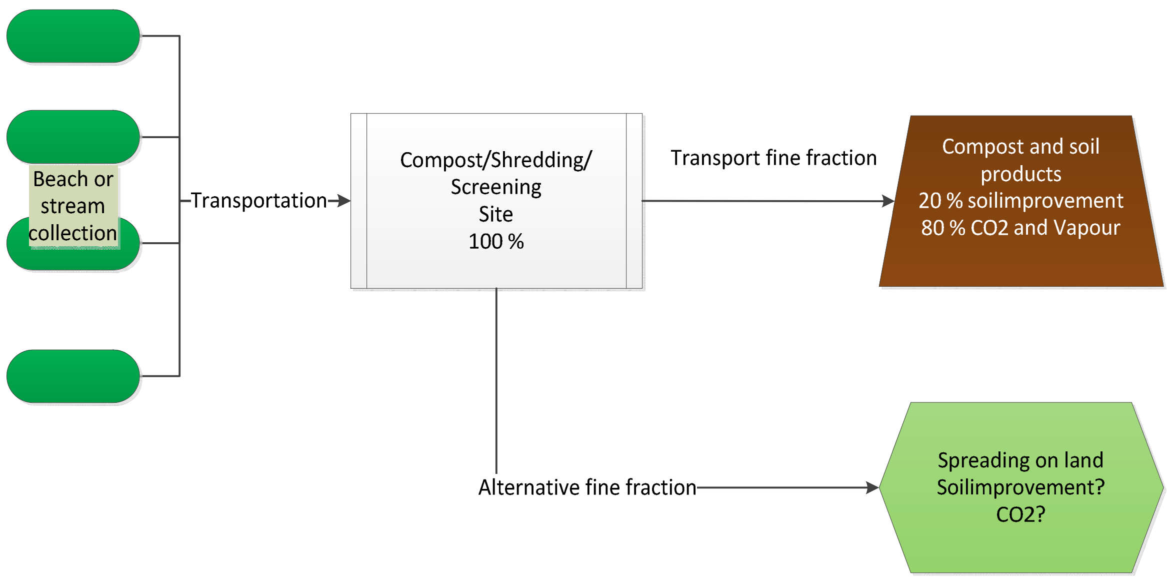


Figure 3: Seaweed and Stream Weed Cuttings today

For Aikan the sand and impurity issue that other AD plants have with these materials is not foreseen to be of importance and since the output product from Aikan today is energy and compost these will be brought out with a solid product instead of ending as bottom sediments in the tank.

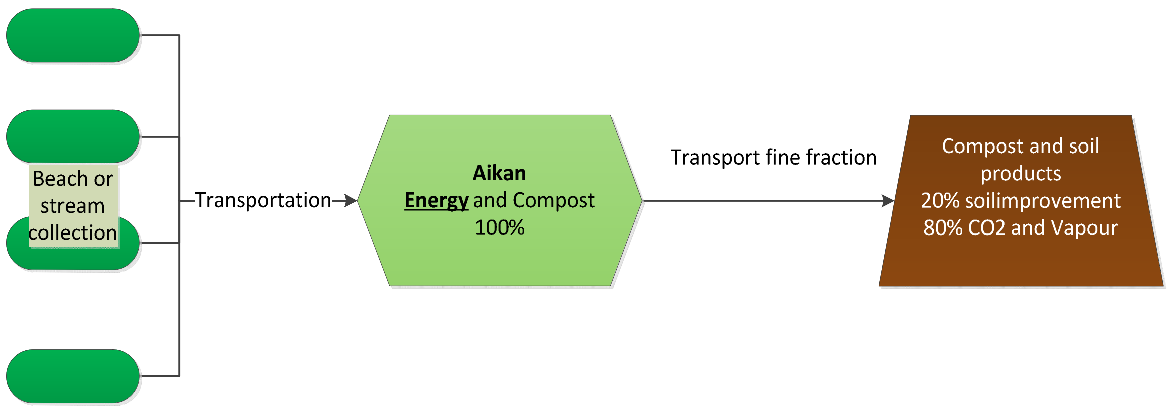


Figure 4: Aikan model for Seaweed and SWC

For seaweed and SWC the values increase in the same manner, but it is still to be shown how low the cost for treatment can get.

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Rapportnr.:	AR-17-CA-00575050-01
Batchnr.:	EUDKVE-00575050
Kundenr.:	CA0001634
Modt. dato:	14.08.2017

Analyserapport

Prøvested:	Tang-Kompost 08-17 - / 20000437
Prøvetype:	Kompost
Prøveudtagning:	14.08.2017 kl. 12:55
Prøvetager:	Eurofins Miljø Vand A/S NIL
Analyseperiode:	14.08.2017 - 19.10.2017

Prøvemærke: Tang-Kompostbunke

Lab prøvenr:	**80408923**	**Enhed**	**Kravværdier Min.**	**Max.**	**DL.**	**Metode**	**¤)**	**Um (%)**
pH værdi	7.8	pH			2	* PD. FAJ. VI 2		
Tørstof	51	%			0.05	* DS 204 mod.		10
Glødetab på tørstof	26	% ts.			0.1	* DS 204		20
Rumvægt	0.60	g/cm³				* DS/EN 13040		
Konduktivitet (Ledningsevne)	22	10 mS/cm			0.05	* PD. FAJ. VI 1		
Ledningstal	36	10 mS/cm			0.05	* PD. FAJ. III 6		
Kompost analyser								
Solvita kompost test	4	farve unit				* Miljøprojekt 470:1999, pkt 3.4.3 Visue		
Stabilitetsgrad	Meget stabil					* Miljøprojekt 470:1999, pkt 3.4.6 Bereg		
Selvopvarmning	20					* Miljøprojekt 470:1999, pkt 3.4.4		
Partikler < 2 mm	27	% ts.				* DS 405.9 Sigtning		
Partikler < 5 mm	62.1	% ts.				* DS 405.9 Sigtning		
Sten > 5 mm	33.3	% ts.				* DS 405.9 Sigtning		
Plast > 2 mm	0.00	% ts.				* Projekt 470:1999 Sigtning		
Metal > 2 mm	0.00	% ts.				* Projekt 470:1999 Sigtning		
Glas > 2 mm	0.00	% ts.				* Projekt 470:1999 Sigtning		
Sum af synlige urenheder >2 mm	0.00	% ts.				* Projekt 470:1999 Sigtning		
Reaktionstal	8.1					* PD. FAJ. III 8 Beregning		6
Respiration								
Respiration pr.g org. tørstof	3.3	mg O2/g ts.				* Miljøprojekt 470:1999, pkt 3.4.2		
Uorganiske forbindelser								
Calciumcarbonat, kalkvirkning	4.8	% ts.			0.5	* PD. FAJ. III 5 m.		20
Brintioner, ombyttelig	0.1	mEq/100 g				* PD. FAJ. III 10	A	
Kalium (K)	370	mg/100 g			0.2	* FIA	B	
Kaliumtal	9.5	mEq/100 g ts.				* PD III 15 Beregning		
Calcium (Ca)	320.00	mg/100 g ts.				* ICP-OES	B	
Calciumtal	16.00	mEq/100 g ts.				* PD III 15 Beregning		
Natrium (Na)	75	mg/100 g ts.			0.2	* ICP-OES	B	
Natriumtal	3.3	mEq/100 g ts.				* PD III 16 Beregning		
Magnesium (Mg)	28	mg/100 g ts.				* ICP-OES	B	
Ammoniak+ammonium-N	0.66	kg/ton				* Projekt 470:1999		
Ammoniak+ammonium-N	0.40	kg/m³				* Beregning		

Tegnforklaring:

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>: større end
#: ingen parametre er påvist
DL.: Detektionsgrænse
*): Ikke omfattet af akkrediteringen
i.p.: ikke påvist
i.m.: ikke målelig
¤): udført af underleverandør

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.
$^{\sigma}$): Usikkerheder på mikrobiologiske parametre angives som logaritmeret standardafvigelse

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Analyseperiode: 14.08.2017 - 19.10.2017

Prøvemærke: Tang-Kompostbunke

Lab prøvenr:	**80408923**	**Enhed**	**Kravværdier Min.**	**Max.**	**DL.**		**Metode**	**¤)Um (%)**
Uorganiske forbindelser								
Nitratkvælstof	< 0.001	kg/ton			0.001	*	Projekt 470:1999	
Nitratkvælstof	< 0.0006	kg/m³			0.001	*	Beregning	
Kvælstof, total	0.77	g/100 g			0.01	*	DS/EN 13654-1	20
Total Nitrogen	7700	mg/kg			5	*	Nordforsk 1975:6	20
Total Nitrogen	4.6	kg/m³				*	Beregning	
Total Nitrogen	1.5	% ts.					Beregning	20
Fosfor, citratopløselig	2400	mg/kg ts.			100	*	SM 3120 ICP-OES	
Fosfor, citratopløselig	0.74	g/l			0.1	*	Beregning	
Fosfor, citratopløselig	1200	mg/kg			100	*	Beregning	
Fosfor, total	2700	mg/kg ts.			50		SM 3120 ICP-OES	30
Fosfor, total	0.83	g/l			0.1	*	Beregning	
Fosfor, total	1400	mg/kg					Beregning	
Organiske samleparametre								
TOC, totalt organisk kulstof	160000	mg/kg ts.			500		ISO 10694 Dumas (TCD)	20
TOC/TN forhold	11						Beregning	
Metaller								
Arsen (As)	< 2	mg/kg ts.			2		SM 3120 ICP-OES	30
Arsen (As) pr.phosphorenhed	< 700	mg/kg TP					Beregning	
Bly (Pb)	12	mg/kg ts.			2		SM 3120 ICP-OES	30
Bly (Pb) pr. phosphorenhed	4400	mg/kg TP					Beregning	
Cadmium (Cd)	0.36	mg/kg ts.			0.05		SM 3120 ICP-OES	30
Cadmium (Cd) pr.phosphorenhed	130	mg/kg TP					Beregning	
Calcium (Ca)	39000	mg/kg ts.			50		SM 3120 ICP-OES	30
Calcium (Ca)	12	g/l				*	Beregning	
Calcium (Ca)	20000	mg/kg				*	Beregning	30
Total calcium som CaCO3	30	kg/m³				*	Beregning	30
Total calcium som CaCO3	49	kg/ton				*	Beregning	30
Chrom (Cr)	28	mg/kg ts.			1		SM 3120 ICP-OES	30
Chrom (Cr) pr.phosphorenhed	10000	mg/kg TP					Beregning	
Kalium (K)	13000	mg/kg ts.			50		SM 3120 ICP-OES	30
Kalium (K)	4.0	g/l					Beregning	30
Kalium (K)	6600	mg/kg			50		Beregning	30
Kobber (Cu)	34	mg/kg ts.			3		SM 3120 ICP-OES	30

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σ): Usikkerheder på mikrobiologiske parametre angives som logaritmeret standardafvigelse

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Metaller							
Kobber (Cu) pr.phosphorenhed	13000	mg/kg TP				Beregning	
Kviksølv (Hg)	0.043	mg/kg ts.			0.01	SM 3112 CV-AAS	30
Kviksølv (Hg) pr.phosphorenhed	16	mg/kg TP				Beregning	
Magnesium (Mg)	2800	mg/kg ts.			10	SM 3120 ICP-OES	30
Magnesium (Mg)	0.86	g/l				Beregning	30
Magnesium (Mg)	1400	mg/kg				Beregning	30
Nikkel (Ni)	7.7	mg/kg ts.			1	SM 3120 ICP-OES	30
Nikkel (Ni) pr. phosphorenhed	2900	mg/kg TP				Beregning	
Svovl (S), total	1900	mg/kg ts.			50	SM 3120 ICP-OES	30
Svovl (S), total	0.58	g/l				Beregning	20
Svovl (S), total	970	mg/kg				Beregning	20
Zink (Zn)	130	mg/kg ts.			1	SM 3120 ICP-OES	30
Zink (Zn) pr.phosphorenhed	48000	mg/kg TP				Beregning	
Vurdering							
Kationkapacitet, CEC	31.2	mEq/100 g ts.				* Beregning	
Oplysninger fra prøvetager							
Antal delprøver	48						C
Prøvetagningsmetode	Parti					PD vejledning, maj 1997	C
Partistørrelse (ca. tons)	60						C
Prøvetagningsudstyr	Ske						C
Produkttype	Kompost						C

Underleverandør:

A: OK Laboratorium for Jordbrug
B: Eurofins Agraranalytik Deutschland (Jena)
C: Eurofins Miljø Vand A/S (DS EN ISO/IEC 17025 DANAK 555)

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#: ingen parametre er påvist
DL.: Detektionsgrænse
*): Ikke omfattet af akkrediteringen
i.p.: ikke påvist
i.m.: ikke målelig
¤): udført af underleverandør

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.
$^{\sigma}$): Usikkerheder på mikrobiologiske parametre angives som logaritmeret standardafvigelse

Eurofins Miljø A/S
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Att.: analyserAIKAN@solum.com

Rapportnr.:	AR-17-CA-00575050-01
Batchnr.:	EUDKVE-00575050
Kundenr.:	CA0001634
Modt. dato:	14.08.2017

Analyserapport

Prøvested:	Tang-Kompost 08-17 - / 20000437
Prøvetype:	Kompost
Prøveudtagning:	14.08.2017 kl. 12:55
Prøvetager:	Eurofins Miljø Vand A/S NIL
Analyseperiode:	14.08.2017 - 19.10.2017

Prøvemærke: Tang-Kompostbunke

Lab prøvenr:	**80408923**	**Enhed**	**Kravværdier Min.**	**Max.**	**DL.**	**Metode**	**¤)Um (%)**

20.10.2017

Kundecenter
Tlf: 70224231
G10@eurofins.dk

Sara Skovsende Mørk
Kunderådgiver

Tegnforklaring:

<: mindre end
>: større end
#: ingen parametre er påvist
DL.: Detektionsgrænse

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