

# EUDP Urban Energy – Final Report

July 2016

*Prepared by Renew Energy A/S*



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## 1 Project Details

Project title	Urban Energy Pre Project
Project identification (program abbrev. and file)	EUDP 2014-II, j.nr. 64014-0553
Name of the programme which has funded the project	EUDP Technology area: Biomass
Project managing company/institution (name and address)	RENEW Energy A/S Kullinggade 31 5700 Svendborg
Project partners (Name and CVR)	RENEW Energy A/S (CVR no. 30814371) Syddansk Universitet (CVR no. 29283958) NGF Nature Energy Biogas A/S (CVR no. 34614091) Municipality of Nyborg (CVR no. 29189722) Greatop Science and Technology Development (Denmark) ApS (CVR no. 35861637) NC Miljø A/S (CVR no. 28305141) Nyborg Forsyning & Service A/S (CVR no. 25535456)
Date for submission	June 30, 2016

## 2 Project objective and results

### 2.1 In English

The project partners want to demonstrate a sustainable energy and nutrient recovery solution for urban waste management based on biogas plant technology.

The inhomogeneous nature of household waste poses challenges to be resolved: is it possible to produce, on the basis of simple mechanical technologies, a biopulp allowing for constant and stable biogas production?; how important is the contamination issue?; what kind of compounds can we expect to find in biopulp?

The success of such concepts lies within securing a well documented and positive business case. The pre-project will develop a business case that documents the whole value change of the Urban Waste concept, going from the waste input to the biogas and fertilizer output.

It is important for the project parties to strengthen business relationships with the Chinese partner CECEP in the course of the project. Activities in the course of the project support such development.

### **2.1.1 Purpose**

The purpose of the project is to conduct a feasibility study on how biogas can recover energy and nutrients from urban waste in a sustainable way (economically, environmentally and politically). The project is a Danish-Chinese collaboration, which is expected to lead to export of Danish technology suitable for urban areas in China.

### **2.1.2 Results**

Unsorted household waste is a difficult material to handle and places high demands on the equipment. There is still a need to develop the Haarslev waste food depacker system to optimize capacity and the quality of the product streams.

With the income for waste treatment and biogas sales, there are good economical basis for a business case but both parameters are greatly politically dependent.

There is a large market for the treatment of organic waste in China and also a high demand for Danish/European technology. The market and the framework conditions are not fully developed yet and work are in progress to find the best solution for establishing Danish technology-based plants in China.

## **2.2 In Danish**

Projektparterne vil demonstrere en bæredygtig løsning, for energi og næringsstof genanvendelse på husholdningsaffald "Urban Waste"

Affaldets inhomogene karakter giver udfordringer, der skal løses: er det muligt med simple mekaniske teknologier at skabe en biopulp som giver mulighed for en konstant og stabil biogasproduktion?; kan gældende grænseværdier ved udbringning på landbrugsjord overholdes?; hvilke forbindelser må vi forvente at finde i biopulp?

Konceptets succes afhænger af, at der tilvejebringes en veldokumenteret og positiv business case. For-projektet vil udvikle en business case, der dokumenterer hele værdikæden af "urban waste" konceptet, med udnyttelse af husholdningsaffald til biogas produktion og næringsstof recirkulering.

Parterne har ønsket, at der i projektforsøget knyttes forretningsrelationer til den kinesiske partner CECEP Lightning Management Co (Greatop), og projektet understøtter aktiviteter til at styrke denne relation.

### 2.2.1 Formål

At foretage et feasibility studie af hvordan et biogasanlæg kan anvendes til at genindvinde energi og næringsstoffer i "urban waste" på en økonomisk, miljømæssig og politisk bæredygtig måde. Projektet er et dansk-kinesisk samarbejde, der ventes at medføre eksport af dansk teknologi velegnet til urbane områder i Kina.

### 2.2.2 Resultater

Usorteret husholdningsaffald er et besværligt materiale at håndtere og stiller store krav til udstyret. Der er stadig behov for udvikling af Haarslev waste food depacker systemet for at optimere kapaciteten og kvaliteten af produktstrømmene.

Med indtægt på affaldsbehandling og biogas salg er der gode forudsætninger for en fornuftig business case men begge parameter er i høj grad politisk afhængige.

Der er et stort marked for behandling af organisk affald i Kina og samtidig en stor efterspørgsel efter Dansk/Europæisk teknologi. Markedet og rammevilkårene er ikke fuldt udviklet endnu og der arbejdes stadig på at finde den bedste løsning for at etablere Dansk teknologibaserede anlæg i Kina.

## 3 Executive summary

The project partners have in the period from January 2015 to July 2016 executed the Urban Energy Pre project. The conclusion of the project was approx. three month postponed due to additional trial test on the pre-treatment equipment and difficulties in securing source separated waste of the right composition.

The trial test on the pre-treatment equipment showed that the content of plastic and other impurities in the biopulp is a large challenge. It is expected that this is a key issue to solve before investors will risk using the technology for household waste separation.

The main conclusion of the project is that a positive business case for set-up of an Urban Waste plant could be established, economically and technically. Economically, the revenue stream rests on revenue streams in which prices are decided politically.

Results from the project is already being utilized in development of the pre-treatment technology and Renew Energy' design.

A good business relationship have been established between the Chinese and Danish companies and Renew and Greatop are developing a strategy for the entering of the Chinese market with Renew Energy' Urban Energy design.

## **4 Project objectives**

The overall aim of the project was to conduct a feasibility study on how biogas can recover energy and nutrients from urban waste in a sustainable way (economically, environmentally and politically). A spin-off of the project was to foster Danish-Chinese collaboration, enabling export of Danish technology to China.

The seven partners have quite a diverse background and structure. Hence the start-up of the project involved a kick-off in which project plan, work packages and deliveries were unfolded.

In general, the project where steered through formal project planning and tight budget follow-up.

SDU were in lead of activities in **WP1, the value streams in the pre-treatment**. Tests was planned together with NC Miljø, Nyborg Forsyning and Nyborg Municipality; Renew Energy following the activities closely and assisted with manpower during the trial tests.

It turned up to be difficult to perform the tests of waste on a level as planned. The waste collected was not having adequate quality and the pre-treatment process did not live up to expectations. As a consequence, the quality and the quantity of the biopulp didn't live up to expectations; additional tests had to be performed, and the business case had partly to rely on Renew Energy's experiences from other biogas projects (on top of the data collected via WP1). Especially collection of source separated waste showed to be more difficult than anticipated. Nyborg Municipality was running a project parallel to the Urban Energy project where source separation of household waste was tested. The organic fraction was mostly garden waste. Getting source separated waste from other municipalities that was running source separation at a higher level was investigated but without success. The project was finalized 3 months later than planned due to the unforeseen circumstances.

NC Miljø, host of the pre-treatment facility, was sold during the project and the facility was at the end of 2015 closed down and the equipment was moved to a new facility in Heden, Funen. This created a natural ending for the trial testing and did not give opportunity for further optimization of the test results.

**WP2, market analyses of the fertilizer fractions**, were a sub-project conducted by Renew Energy. The analyses have outlined the market for fertilizer fractions as a desk study. The quality of the biopulp in WP1 did not enable an in-depth dialogue with the actors in the industry.

A main delivery in the project is **WP3, a business case of a total plant for urban waste**. The work rests on the technical- and financial data from Renew Energy, enabling calculation of CAPEX, OPEX and revenue

streams. The Haarslev waste food depacker is in operation in a number of other facilities around the world and a reference site in Sweden was visited. Parallel to the Urban Energy project was Renew Energy involved in trial test of the Haarslev waste food depacker in USA as well.

The business case was made in corporation with 1stMile, and NGF Nature Energy was consulted in the process.

The work in **WP4, feasibility study Changzhou** was lead by Greatop, heavily supported by Renew Energy. The feasibility study has developed as planned, and in the process, there has been an intense dialogue.

The work performed in WP 2 through 4 have basically been delivered according to plan, and it can be mentioned, that Renew Energy and Greatop have developed their business corporation in other areas.

The **main risk** seen in the project is primarily the issue of safeguarding waste of sufficient quality and quantity. In addition the business case has had to use experiences from other biogas plants due difficulties of securing stable processes in the pre-treatment phase.

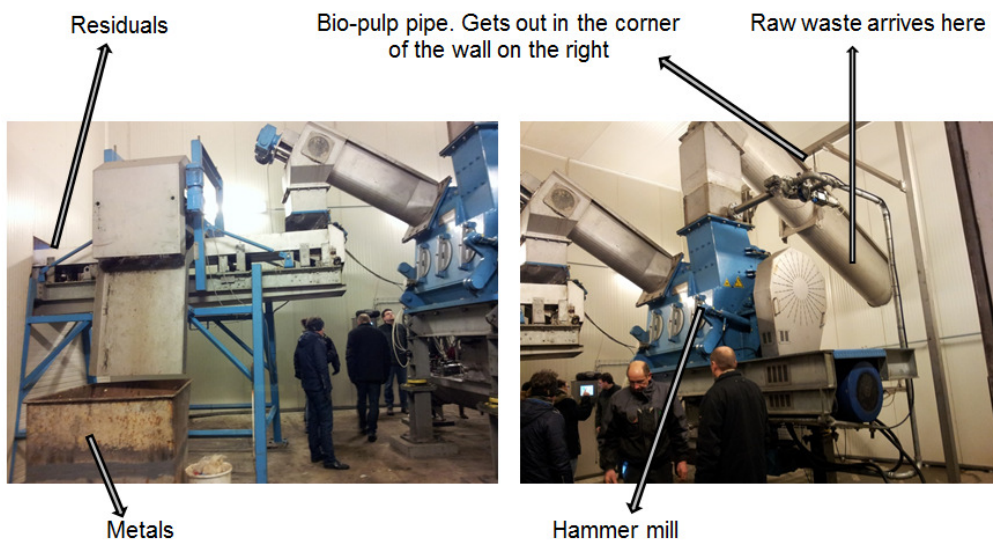
## 5 Project results and dissemination of results

The results of the work in each work package is described in detail in the reports attached as annex:

- **WP1: Urban Energy – Waste Based Biogas** (including annex)
- **WP2: Market analysis of the fertilizer fractions**
- **WP3: Business Case** (including annex')
- **WP4: Feasibility Study for Demonstration Project in Jiangsu Province**

The results in each work package have been highly influenced by the outcome of work package 1: *Test run on household waste at NC Miljø's facility in Nyborg to analyse the different value streams and the technical capacity*. The findings in this work package is described and presented in Annex: **Urban Energy – Waste Based Biogas**.

Picture below is showing the Haarslev waste food depacker.



The major finding from the test runs was that the demonstrated technology had great difficulties in showing the desired capacity and quality of the biopulp. The purity test detected high contamination of the biopulp ranging from 5.2 to 50.5% of TS (g of impurities per g of TS). Germany and Sweden have already set limits for land fertilizing with organic household waste digestate to 0.5% of TS. Consequently, under these conditions the digestate observed in this study could not be used for fertilizing. Even if Denmark does not have the before mentioned contamination limits yet, it is to be expected that farmers could be reluctant to use fertilizers of this quality on their land.

The following conclusions to the research questions can be made:

1. It could not be demonstrated by the test runs performed, that it is feasible to use the simple mechanical pre-treatment, as the one in place at N.C. Miljø, to recover organics from municipal household waste and use them for biogas production. The feasibility was compromised by:
  - The achieved low operating capacity during tests, displaying a maximum of 3.9 t/hour, which is only a fraction of the designed capacity of 10-15 tons/hour
  - The visible contamination (contaminants like light plastic pieces and other materials > 2.5 mm) of the biopulp
2. A stable biogas production was achieved with the biopulp during simulations in continuously stirred tank reactors, with a BMP varying between 23 – 48 L wet gas/d and a methane content of 50 – 63%.
3. The digestate emerging at the biogas plant meets all environmental parameters set by law.



It was obviously that a post or pre-treatment is a requirement for the demonstrated technology if a proper quality of the biopulp shall be secured. A hydro cyclone test (type of centrifuge), applied on one extra waste stream of supermarket waste, showed a reduction of contamination in the biopulp of 38% (glass removal mostly). This test was not part of the main observations but was used to see whether it could be a solution for the purity problem that occurred with household waste biopulp. In addition, some biopulp samples were centrifuged and the contamination of the resulting liquid was analysed. It showed that one solution to the contamination issue could be to accept not using the digestate as a fertilizer on land, separate it and use the recovered solid fraction for energy (combustion, thermos-gasification) and the liquid on land.

Two fertilizer products are produced in the urban energy plant. A solid compost with fertilizer value and great soil amendment characteristics and a liquid ammonium sulfate of 38 %. The composition of the solid fertilizer product will be highly influenced by the impurity level in the biopulp.

The commercial fertilizer market has had a decrease in the 90'ies, but has been somewhat stable since 2002. The supply of livestock fertilizer has been somewhat stable the past 24 years. The amounts of fertilizers produced at the Urban Energy plant are little compared to the entire fertilizer market. The compost is however only expected to be used locally and will depend on the local conditions.

It is expected that the greatest stakeholders for the compost will be the local plant breeders and other farmers who doesn't have milk production. Additionally the community and the local golf courses may have an interest in using the compost for their green areas. The use of the compost however depends on whether it meets the current requirements in the Danish Order *BEK 1650 of 13/12/2006 Bekendtgørelse om anvendelse af affald til jordbrugsformål* and the new order which is on the way.

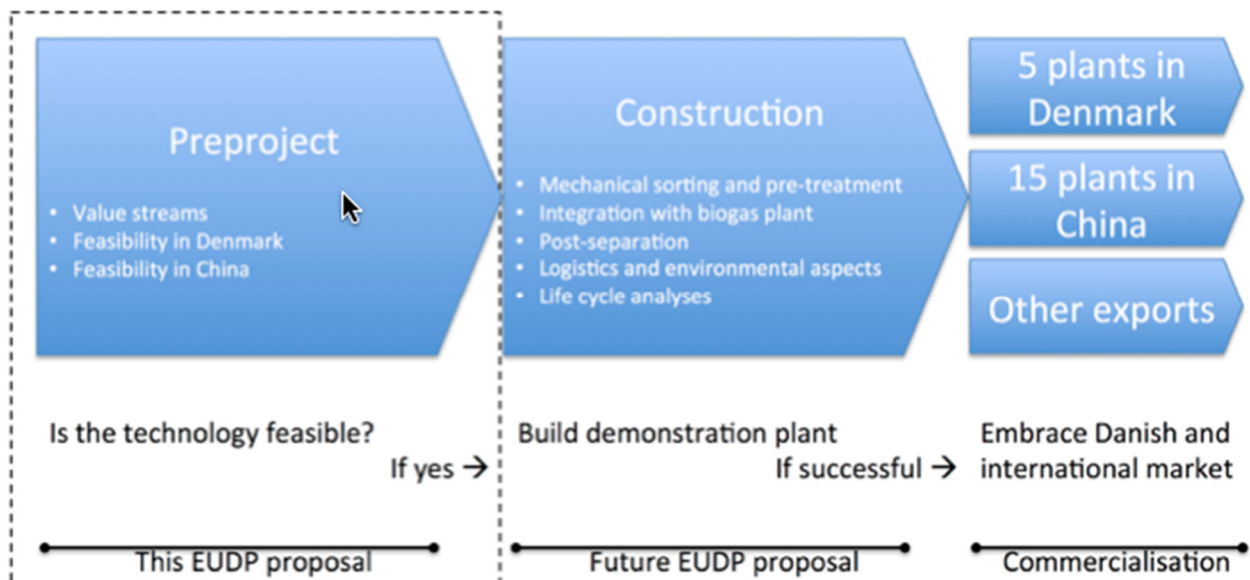
The ammonium sulfate is expected to be sold to wholesale companies, especially Dan Gødning, who is a large producer of liquid fertilizer can be a great stakeholder. The ammonium sulfate may be blended into and used to produce products already in their product range.

The following shows a stakeholder map regarding the fertilizer products of the Urban Energy plant.

		<b>Level of Interest</b>	
		<b>Low</b>	<b>High</b>
<b>Power</b>	<b>Low</b>	<p><b><u>A. Minimal Effort</u></b> DLG Yara Denmark BioNutria Golf courses Private people Agricultural advisors</p>	<p><b><u>B. Keep Informed</u></b> Industry association for biogas</p>
	<b>High</b>	<p><b><u>C. Keep satisfied</u></b> Danish government Municipalities</p>	<p><b><u>D. Key Players</u></b> Farmers Dan Gødning</p>

The **major aim of the Urban Energy project was to set up a business case** that could be the basis for the discussion for the investment in a demonstration project in Ørbæk, Funen. NGF Nature Energy owns a site that has environmental approval for a manure based biogas plant and preliminary considerations have been that this site could be used for a demonstration project. A successful demonstration of the technology and a positive business case for handling household waste will required as base for decision.

The figure below shows the expected plan for commercialization set forth in the EUDP application.



The business case for the Urban Waste plant shows net income of 28,7 mDKK, operating costs of 6,5 mDKK and an earnings before interest and tax (EBIT) of 22,2 mDKK. Drivers of the revenue is sale of methane and tipping fee.

With an investment of 52,2 mDKK, the discounted cash flow is very positive. The discounted cash flow in the 15-years operation period is 110,8 mDKK.

The main revenue drivers are politically decided. Hence a sensitivity analyses has been made. This analyse shows that revenue from the two main sources both can decline with approx. 50% before the discounted cash flow turns negative.

The Urban Energy project did however not succeed in demonstrating that the technology is capable of dealing with household waste, both sorted and unsorted, in a desired way. Further development of the pre-treatment technology is needed and new demonstration test of the technology will be required before this technology can be applied for separation of household waste. The major issue is the concentration of impurity in the biopulp.

The pre-treatment technology is in operation at two of NGF Nature Energy's biogas plants in Denmark where discharged food waste from the retail marked is separated. These plants have been installed parallel whit the Urban Energy project and the learning's from the trail test have been integrated in some part of these plants.

The task in WP 4 was to preform a **Feasibility Study for a Demonstration Project in Jiangsu province**. The purpose of this task is to assess the waste and evaluate barriers in China. The report in Annex 4 gives a thorough introduction of kitchen waste and household waste, respectively. The findings are that the off take markets and subsidies are extremely important for anaerobic digester plants, and results of this investigation are provided in chapter 5 and chapter 6.

The work in WP 4 have been of high value for Greatop and the Chinese owners and given them a much better understanding of how to enter the market for organic waste handling and what possibilities and barriers there is for bringing a Danish concept to China. Collaboration between Renew Energy and Greatop is being developed with the perspective of bringing Renew Energy's Urban Energy concept to China. As a direct result of the trial tests, a different pre-treatment technology has been chosen.

The project has so far not resulted directly in increased turnover, exports or employment. It is however expected that it will materialize in increased export to specially China.

The learning's in the project have high value for Renew Energy who is executing two projects similar to the Urban Energy project in USA and Iran. The tested pre-treatment equipment will with improvements be utilized in these projects. ☐

## **6 Utilization of project results**

The project results will be used in Renew Energy's design and choice of strategy. It is clear that unsorted household waste will have a highly negative effect on the pre-treatment equipment performance and this learning have been included into the Urban Energy concept.

Politically and strategically, Nyborg Municipality and Nyborg Forsyning will be able to use the results as guidance for the policy objective to achieve a higher degree of resource recycling of especially organic waste. Other Municipalities will also be looking at the results.

The results will be a natural part of other research and developments at SDU.

To get a better overview of how to implement a Danish technology driven biogas plant in china, a concrete project is needed. Based on the current collaboration Between Nanjing municipality, Greatop and Renew Energy, the three parties have agreed to use currently available information and data. Renew is assisting Greatop to achieve the 'Prequalification' in order to get tender from Nanjing municipality.

The results of the trial test with the pre-treatment technology showed clearly that improvements should be made if the technology should be competitive with other technologies for separation of household waste.

It was never the intention that the project should take out patents.

## 7 Project conclusions and perspective

The main conclusion of the project is that a positive business case for set-up of an Urban Waste plant could be established, economically and technically. Economically, the revenue stream rests on revenue streams in which prices are decided politically. Technically, the project demonstrated that an Urban Waste plant is feasible.

In order to make the Urban Waste process robust, a further development is required in to improve the quality and quantity of the biopulp. Main areas for required improvement are:

- Improving the quality of waste by source separation at the households, which implies information campaigns in order to convince the necessary diligence and hereby improve the efficiency
- Improve the pre-treatment process, possibly by narrow the screen size of the hammer mill, leading in smaller particles and less adhesion of multiple materials and therefore better separation

The project may influence that a stronger focus on source separation is created. Source separation will help the separation plants achieve a better biopulp quality at a higher capacity.

The project have materialized in new markets and opportunities for Renew Energy,

## 8 Annex

The deliverables for each of the Work Packages is attached to the final report as the following Annex':

- **WP1: Urban Energy – Waste Based Biogas** (including annex)
  - **Database**
- **WP2: Market analysis of the fertilizer fractions**
- **WP3: Business Case** (including annex')
  - **Urban Energy plant design**
  - **Business case - Feasibility**
- **WP4: Feasibility Study for Demonstration Project in Jiangsu Province**