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Pilot Case Study

Fossil fuel to green energy in waste management vehicles

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Commissioned by: Kolding Municipality, Denmark

Contact: Martin Pedersen Stub, Project Manager in Circular Economy, Kolding Municipality, mastu@kolding.dk

Introduction

Kolding Municipality has laid the groundwork for its green transition with its municipal sustainability strategy. In collaboration with Danish Technological Institute, the municipality has prepared the first phase of a conversion plan for the fleet of vehicles and machinery in the Municipal Waste Department, in order to reduce CO_2 emissions.

The conversion plan was divided into two phases. In phase 1, an overview of the fleet in terms of fuel consumption, CO_2 emissions and costs for each individual vehicle and machine was created. In phase 2, an overview of possible technology choices within four main fuel tracks was made. The department needed an overview of pros and cons for the viable choices of propellants. The four fuels tracks are:

- Diesel
- Electricity
- Biodiesel
- Hydrotreated Vegetable Oil (HVO)

Procurement process

In the project's early considerations natural gas and hydrogen were also included, but were deselected as realistic possibilities for two reasons:

1. It is not economically viable for the municipality to establish an infrastructure that supports these fuels. The fueling system alone would cost a several million euro investment.

2. It requires a lot of energy to produce liquid

hydrogen. Danish Technological Institute estimates a 90% loss in the energy conversion, which means that for every 10kW of energy used in production 1kW ends up as propellant in the vehicle. Because of this, liquid hydrogen is only an efficient green propellant when produced with 100% green energy. Comparatively close to 100% of the produced energy ends up as propellant in the vehicle, in electric vehicles. Although a part of the Danish natural gas consists of CO_2 neutral biogas – approx. 20% – the gas is still considered a fossil fuel and the CO_2 reduction is thus limited, especially when compared with the other fuels included in this phase.

The advantages and disadvantages of the remaining four fuel tracks were analysed and the result is summarised in a spreadsheet (see below). It forms a succinct and clear overview of investment needs, fleet economy and CO_2 saving potential within the four fuel tracks. The spreadsheet contributed to the municipality's decision-making processes in choosing the right strategy for reducing CO_2 emissions of the vehicle park.

Although specific vehicles and machines were recommended in the spreadsheet, these might not necessarily be the best choices in two to three years, as the market is developing rapidly especially for electric trucks. The case examples in the spreadsheet are based on the trucks and machines that are currently available in the marked today and are intended as a guideline for future procurements of passenger cars, vans, cranes, and trucks and machines, respectively.

During the process of examining the benefits and costs of different fueling systems and the infrastructures required, the Waste Department had to decide which strategy to employ in the transition from fossil fuel to green energy.

Kolding Municipality **Scenarios for green conversion**		**Baseline 2021**			
		CO2 emission [kg]	192.275	Total costs	324.549 €
		CO2 index [--]	100%	Fuel costs	94.207 €
Year	**Current vehicle**	**Diesel**	**Biodiesel**	**HVO**	**Electric**
2022	263800 Volvo comprimator 3 axles chassis	FE 6x2 Euro VI chassis 2-room compressor	FE 6x2 Euro VI chassis 2-room compressor	FE 6x2 Euro VI chassis 2-room compressor	FE 6x2 Electric chassis 2-room compressor
	266500 DAF CF-series, hooklift 3 axles chassis	FE 6x2 Euro VI chassis hooklift	FE 6x2 Euro VI chassis hooklift	FE 6x2 Euro VI chassis hooklift	FE 6x2 Electric chassis hooklift
	Investment needs: infrastructure	0 €	14.783 €	14.783 €	282.216 €
	Investment needs: vehicle	403.166 €	403.166 €	403.166 €	860.088 €
	Expenditure on fuel	-1.075 €	21.771 €	25.937 €	403 €
	Depreciation EUR/year	15.052 €	15.052 €	15.052 €	60.744 €
	CO2 index	99%	80%	80%	78%
2023	265300 Case 695ST - Backhoe Kolding Nord Recycling Station	Volvo L30G with 1 m3 shovel and fork	Volvo L30G with 1 m3 shovel and fork	Volvo L30G with 1 m3 shovel and fork	Volvo L 25 Electric with 0.9m3 shovel and fork
	655400 Case 695ST – Backhoe Kolding Syd Recycling Station	Volvo L30G with 1 m3 shovel and fork	Volvo L30G with 1 m3 shovel and fork	Volvo L30G with 1 m3 shovel and fork	Volvo L 25 Electric with 0.9m3 shovel and fork
	Investment needs: infrastructure	0 €	29.566 €	29.566 €	56.443 €
	Investment needs: vehicle	94.072 €	94.072 €	94.072 €	201.583 €
	Expenditure on fuel	-1.528 €	33.732 €	36.016 €	672 €
	Depreciation EUR/year	9.407 €	9.407 €	9.407 €	20.158 €
	CO2 index	98%	71%	71%	67%
2024	267100 Volvo fm-500 Hooklift 4 axles chassis	FM 8x2 Euro VI chassis with hooklift	FM 8x2 Euro VI chassis with hooklift	FM 8x2 Euro VI chassis with hooklift	FM 8x2 Electric chassis with hooklift
	Investment needs: infrastructure	0 €	0 €	0 €	53.755 €
	Investment needs: vehicle	188.144 €	188.144 €	188.144 €	456.922 €
	Expenditure on fuel	-2.285 €	52.412 €	51.605 €	-13.573 €
	Depreciation EUR/year	28.222 €	28.222 €	28.222 €	65.850 €
	CO2 index	98%	56%	56%	51%

Notes:

"Investment needs infrastructure" for biodiesel and HVO the scenarios includes tank facilities, cabling and foundations and for the electrical scenario connection fee, branch line, charging stations, cabling and foundations. Investments in absolute numbers, ie the amount that must be concretely invested to realize the trasition

"Investment needs: vehicles" includes a obtained budget price for the vehicle or machine.

"Expenditure on fuel" are in relative numbers. In other words, the change in the amount of the EUR that the specific track entails.

"Depreciation" is calculated as 10% current annual depreciation of the car's new price

"CO2 index" is measured against the reference year 2021. CO2 index is accumulated figures.

Spreadsheet of four fuel tracks. Click here to view full size.

The colored fields in the spreadsheet show that electric vehicles have the highest impact, while the investment and expenditure fields show that diesel has the lowest cost. If the department had unlimited capital, a direct transition to electric vehicles would be ideal and have the highest impact. On the other hand, staying with diesel fuel for a few more years, would increase the budget for future spending and allow for a cleaner transition as the local infrastructure and the market in general would mature further.

In the end, the employed strategy was a compromise between the two types of diesel. By setting up a local fueling station for HVO, diesel and HVO can be mixed in relative proportions. This approach gives the department a high degree of control over cost and the ability to have an instant impact on CO_2 emissions.

However, this strategy carries its own challenges, as there is insufficient biomass in the world's stock of waste and surplus material to meet the production demands if biofuel becomes the primary choice of fuel. This will result in the use of virgin materials and put a strain on the biomass quantities required for food and feed production.

The limits on land, water, capital and labour is already creating competition on biomass for food, feed and fuel (see figure 1). This problem will only increase as extreme weather such as droughts and floods increase in frequency and become more widespread, while high levels of CO_2 pollution continues.

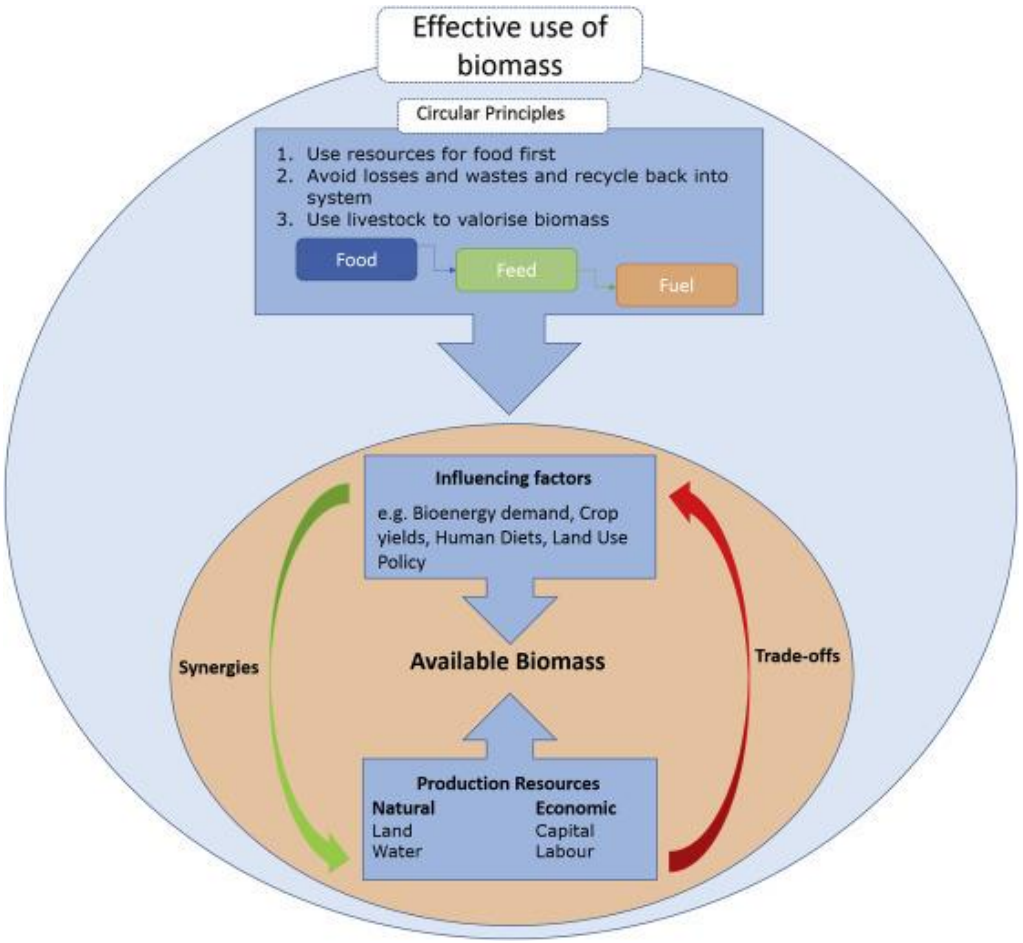

Figure 1 A. Muscat et al. 2020 - The battle for biomass: A systematic review of food-feed-fuel competition

As such, Kolding Municipality views HVO as a transition fuel, which allows them to reduce CO_2 emissions immediately, while waiting for the electric infrastructure and electric vehicles that can carry a heavier load and have an extended range.

The prices on service agreements that the suppliers offer for electric and fossil fuel powered vehicles are similar, and there is no significant reduction in cost per annum in this area.

Another limitation to consider is the lifespan of electric trucks, as the battery pack has an expected life span of only eight years - after which the consumer is expected to invest in a new vehicle. The short lifespan of the battery pack creates needless environmental waste, as many other parts of the vehicle last much longer. A more modular approach, where single parts can easily be replaced by a mechanic, would prolong the lifespan of each module significantly, as is the case with fossil fuel-powered vehicles.

Results

Kolding Municipality chose to invest in HVO as a financially viable option that allows for instant reduction of CO_2 emissions as a first step towards their green transition. HVO allows for an immediate transition, as most trucks can already run on this fuel type. It reduces CO_2 emissions on six trucks immediately (92 tons of CO_2 reduction), and eight trucks and one 3.5t vehicle within two years (135 tons of CO_2 reduction in total).

Advantages of HVO

Immediate impact, control over CO_2 reduction vs. expenses, low cost of infrastructure, most vehicles can use HVO without modification.

- 47.74% CO_2 reduction immediately after installing the HVO fuel tank.
- 70.21% CO_2 reduction after the first year

Disadvantages of HVO

Risk of price increase and undesirable production methods due to increase in demand, high fuel prices.

Lessons learned

- There is no single right approach to vehicle fuels, as all of them have drawbacks and harm the environment in various degrees at different stages of their respective lifecycles and/or production of fuels.
- Remarkably, infrastructure turned out to have a much higher impact on the overall calculations than expected. It is interesting that this topic and the hidden costs associated with this aspect are rarely brought up as a barrier.
- Electric vehicles can carry less weight and have a shorter range, which means that more vehicles are needed to cover the same number of tons per hour. This means increased emissions from the production of vehicles and an additional need for infrastructure such as power supplies and cabling, connection fees, local fuel tanks etc. This should be included in the considerations when aiming at reducing CO_2 emissions. Neglecting to include the development of supporting infrastructure, by focusing exclusively on vehicles, produces a skewed image, where the environmental and monetary cost of transitioning to green energy is hidden. This increases the risk of producing faulty assumptions and strategic choices, which could lead to unnecessary environmental damage.

PROJECT CONTACT
procirc@rws.nl

PROJECT WEBPAGE
https://northsearegion.eu/procirc/