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Residual animal fat and fish for biodiesel production. Potentials in Norway

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ABSTRACT

The potential for biodiesel production based on utilization of residual animal fat and fish in Norway is estimated. This is based on a study of the amounts of residual fat that is possible to recover from grease traps in Bergen. Additional data from Trondheim and Oslo facilitated up-scaling to estimating national potential for utilizing this residue stream for biodiesel production. This is supplemented with data on residues from slaughterhouses and poultry, as well as the fishing industry. The results indicate that Norway has the potential for producing large amounts of biodiesel from these residue sources.

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1. Background

The European Union has realized that the biofuels targets for 2010 of 5.75 % share of the market for petrol and diesel in transport is not likely to be met [1]. This will be a setback in meeting climate change commitments and the development of environmentally friendly security of supply based on renewable energy sources. Therefore, it is necessary to develop knowledge of the potentials of new biofuels production possibilities. Replacing fossil diesel use with biodiesel in Norway has some clear limitations. The growing of rape (*Brassica napus*, *Brassica rapa*) for producing oil for biodiesel has previously been shown to face major barriers in the form of

unfavorable climate conditions and environmental constraints [2]. It is thus necessary to look at other raw materials than virgin oils of rape, soy and sunflower. Utilization of residual materials is of particular interest. Used cooking oil has been utilized to a certain degree, and the BioDieNet (“Localised production and supply of biodiesel from used cooking oils”) project has currently assessed the biodiesel production based on used cooking oil in Europe [3]. BioDieNet was funded by the European Commission’s programme Intelligent Energy Europe (IEE). It was a 3-year project that started in 2007. In this project biodiesel from used cooking oil in Holland, Italy, Portugal, Spain, Germany, Hungary, Norway, Romania, Bulgaria and the United Kingdom constitute about

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13 % of the biodiesel currently produced in EU-25. This is based on the estimate that the total biodiesel production in the EU-25 in 2005 is 3.2 million tonnes [4]. It has been the interest to also look at other residue materials, and the utilization of residual animal fat for biodiesel production has thus been focused in the study giving basis to the current article.

2. Scope

The article is based on a study of the potential for utilizing the content of grease traps in Bergen, the second largest city of Norway, for biodiesel production. Up-scaling of the potentials to national level is carried out by gathering information from the largest and second largest city, Oslo and Trondheim, as well as drawing on national population data.

In addition to the trapped fat in grease traps, other forms of residual animal fat are considered as well. This includes residues from slaughterhouses and the poultry industry, as well as from the fish processing industry. This encompasses both land-based and coastal operations, such as fish farming, as well as dumping at sea.

3. Methods

Two different approaches have been applied. A bottom-up and a top-down approach.

3.1. Bottom-up: questionnaires

A list of all installed grease traps in restaurants and larger kitchen facilities in Bergen as of Jan 1st 2006 was obtained from the Water and Discharge department in Bergen City. Records of these facilities are kept because each facility with an installed grease trap must report annually of their status to the municipal Water and Discharge department. A questionnaire was mailed out to the operators of each of the grease traps on the list. This amounted to a total of 185 questionnaires, one for each installed and operative grease trap.

In the questionnaires it was asked who empties the grease trap, the size of grease trap and how often it is being emptied. With these questions we would get an indication of:

- 1) How much animal residues is being collected from grease traps in Bergen, based on a bottom-up approach.
- 2) Who collects the animal residues from grease traps in Bergen and their share of this market.

3.2. Top down: interviews

The two largest animal fat collecting companies in Bergen were subjected to interviews. They were both group interviews with two persons from the companies and one person from WNRI. The purpose of the interviews was to obtain top-down data as basis for the estimation of total collected animal residues from grease traps in Bergen. Supplementary interviews by telephone and e-mail with a range of persons were carried out and indicated where referred to.

The survey of the situation in Trondheim was carried out with basis in interviews with two central actors connected to Trondheim Municipality's operation of the grease traps in Trondheim. The information from Oslo is based on interview with the City Municipal central actor Oslo Water and Discharge section. Information about fat from poultry and slaughterhouses is obtained through interview with Norsk Protein AS. Data for the estimation of fish residue potentials were based on surveys of available literature.

4. Results

4.1. Response on questionnaires and interviews in Bergen

72 of the questionnaires were answered. This is a response rate of 38.9 %, which might appear to be low, but when considered in light of the top-down information described below, it actually gives good basis to the estimations. These 72 grease traps were reported to provide in total 125 tonnes (t) material. A total of 196 collections were carried out per year on these grease traps. By multiplying the amounts of the individual grease traps with the number of collections we obtain a total of 325 t per year. The average delivered amount per year from each of the grease traps is thus slightly above 4 t (water and fat).

From the questionnaires it was revealed that total amount collected from grease traps and delivered to the disposal site in Rådalen was about 357 t in 2005. The amount delivered to Rådalen is determined with basis in the percentage of dehydrated fat residue in comparison with the delivered total (fat with water). In 2005 this was 13.9%.

The findings imply that the 72 firms, who have responded to the questionnaires, deliver approx. 90% of the total volume received at the Rådalen disposal site. The remaining 114 firms, who were non-responders in the questionnaire survey, deliver about 10% (approx. 34 t). In addition, the water used for cleaning the grease traps is also sucked into the holding tank of the collecting vehicle. This water is being delivered together with the content of the grease traps. In other words, there is being delivered more fat with water than the 323 t that has been calculated from the answers on the 72 questionnaires. This makes it reasonable to conclude that these 72 grease traps constitute a larger part of the total number of the operative traps than the 90% indicated above. On the contrary, it must be noted that there is some uncertainty connected to the fat percentage of 13.9, and this is low in comparison with earlier years when this has been in the range 14–24%, with an average of 17.5 %. If this is used, the total amount of fat included water delivered to Rådalen can be calculated to 359 t, just a marginal increase of less than 3 t. This leads us to conclude that the responses from the 72 grease traps represent at least 90% of the operative grease traps in Bergen.

4.2. Trondheim

Trondheim has approx. 350 installed grease traps. 60–70 of these are more than 10 years old (installed before 1995). Trondheim Renholdsverk AS (TRV) pays a significant cost for

getting rid of the fat. The collected fat is mainly utilized in the production of remote heat, in the facilities of Trondheim Municipal Energy in Heimdal, where it is combusted together with other residues.

Trondheim Bydrift AS (TB) is responsible for following up contracts and agreements connected to the grease traps. TRV and to a lesser extent, Norsk Gjenvinning (Norway Recycling), operate on contracts with TB in collecting fat from grease traps.

The percentage fat in the collected content of the grease traps is higher in Trondheim than in Bergen. Based on the information from the two informants it has been calculated that in 2005 a total of 1.34 kt fat (including water) was collected and of this 0.27 kt dehydrated fat was delivered to the combustion facility in Heimdal.

4.3. Oslo

The content of the grease traps in Oslo are collected and pooled together into the residue fraction “wet organic waste”. Oslo has approx. 1600 installed grease traps. It has been estimated by Oslo City Municipal Water and Discharge Department a total of 3000 grease traps is needed to trap all residual fat in Oslo. The estimated total volume to be collected from these is 20.64 kt. With the basis in the data from Bergen and Trondheim it is reason to expect a fat content of 15–20% in the collected volumes. By using the average of 17.5%, this gives a total potential fat volume of 3.61 kt for Oslo. Furthermore, the amount being collected today from 1600 of the total 3000 traps is 53.3% of this, which results in an estimate of 1.93 kt for Oslo.

4.4. Up-scaling to national level

The total population in the three cities Bergen, Trondheim and Oslo, as of Jan 1st 2006, was 946 000. This is 20.4 % of the 4.6 million total population in Norway. The population of Bergen was 220 000, Trondheim 153 000 and Oslo 546 000 [5]. It is here important to note that Bergen, which is a much larger city than Trondheim, has fewer installed grease traps. Furthermore, Oslo has the largest density of grease traps, with 2.93 per 1000 inhabitants. The corresponding numbers for Bergen and Trondheim is 0.97 and 2.29 respectively. In Bergen, this is considered as sufficient by the authorities, while in Oslo it ought to be almost doubled to 3000.

It is here assumed that the total of 2.34 kt residual animal fat collected from grease traps in Bergen, Trondheim and Oslo is an average potential for 919 000 inhabitants. When this average of 2.5 t residual animal fat per 1000 inhabitants is applied to the total population of Norway, the resulting is 11.81 kt residual animal fat per year. With basis in the numbers from Bergen and Trondheim, it appears likely that the estimates from the Oslo authorities are somewhat high. The data from Bergen and Trondheim indicates an average of 4.3 t emptied (water plus fat) annually per grease trap. With 1600 grease traps in use in Oslo this would total 6.88 kt. This translates into 1.20 kt fat when applying the 17.5 % fat content. This is 0.73 kt less than the 1.93 kt calculated from the data supplied by the Oslo authorities. If this is applied, the amount for the three

largest cities in 2005 would have been 1.62 kt instead of the 1.93 kt. These volumes of animal fat and the number of grease traps in the three cities Bergen, Trondheim and Oslo in 2005 are shown in Table 1.

Using this, the national potential for Norway would be 8.16 kt. This corresponds to 1.7 t per 1000 inhabitants on average.

4.5. Fat from fish

Norwegian fishing vessels brought to land 2 671 kt of seafood in 2004 [6]. Foreign vessels delivered 269 kt seafood in Norwegians harbors [7]. In addition 629 kt salmon and trout from fish farms were slaughtered [8]. The total amount of fish processed in Norway in this year was 3568 kt.

With basis in several reports by RUBIN, including [9], it can be concluded that it is only in the period between January 1st and April 30th that whole fish is delivered on shore. The rest of the year all fish is processed off shore and the residues are dumped in the ocean. A large part of the fish caught between January 1st and April 30th are also processed off shore with no utilization of the residues. The Directorate for Fisheries calculates the amount fish delivered on shore as whole fish, including residues (head, intestines, etc).

According to another report by RUBIN [10], by-product constitutes on the average one-third of the weight of whole fish. We have estimated the total theoretical amount of fish by-products to 980 kt. The residues from fish farms must be added to this. Even though much of the slaughtered salmon and trout from fish farms is sold whole, i.e. only intestines removed, there is some by-product generated. With basis in this, it can be estimated that the total amount of by-product being handled in Norway is well over 1000 kt.

Approx. 450 kt fish residues are dumped from the fishing vessels per year [9]. Dumping from the coastal fishing fleet constitutes 50–60 kt of this. RUBIN has estimated that the total amount of by-products from fish is about 630 kt [11]. The utilization is shown in Fig. 1.

As is seen in Fig. 1 it is mainly cod residues that is not being utilized. Of the 142 kt dumped cod residues it is estimated that 42 kt are dumped on shore, the rest from the vessels while still on the ocean.

623 kt by-products from fish is the theoretical maximum available amounts that could be utilized for biodiesel production. Furthermore, it is known that 166 kt of this is being dumped, of which 48 kt are dumped on shore. The 118 kt dumped off shore are not considered easily available. It is

Table 1 – Animal fat potential from grease traps in the 3 largest cities in Norway.

	Animal fat potential (kt)	Number of grease traps
Bergen	0.07	213
Trondheim	0.35	350
Oslo	1.20	1600
Total	1.62	2163

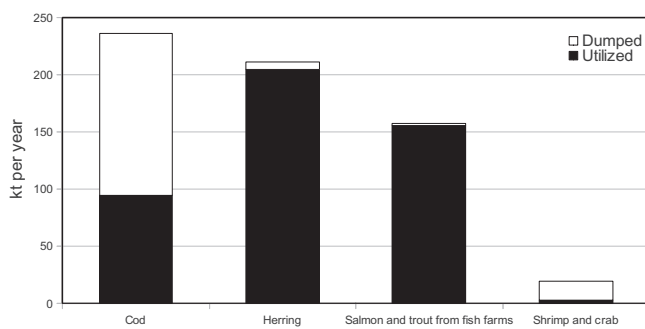


Fig. 1 – Utilization of by-products from various types of seafood (kt per year). Source: [11].

therefore acceptable to estimate the realistically available maximum available amount by-product to 505 kt.

The maximum available fat and oil from by-products of fish in Norway can thus be estimated to approx. 100 kt, by applying an average a fat content of 20%. If, in theory, all by-products from all Norwegian fish harvest was collected the total amount would be more than 900 kt. This amount would give a potential volume of fish fat and oil of close to 200 kt. This implies that 50% of the fish fat that could have been utilized is dumped.

4.6. Fat from slaughterhouses and the poultry industry

A total of 160 kt residues from slaughterhouses is delivered to this collector each year (Source: Interview with Technical Director at Norsk Protein AS, Odd Vinje Lind, on Nov 21st, 2006). This residue constitutes annually about 24 kt animal fat.

4.7. Residual animal fat currently utilized

Of the sources of animal fat we have made an overview of, the fat is mainly used for energy production through remote heating systems and biogas production. The amounts are shown in Table 2.

As shown in Table 2, Scanbio and Norsk Protein are together using about 46 kt purified fat. Unpurified fat are used by BioPlan (0.07 kt), Trondheim Municipal Energy (0.34 kt) and

Table 2 – Residual animal fat currently being utilized.

	Amount (kt)	Type of fat	Purpose
Scanbio	22.7	Purified	Energy production
Norsk Protein	23.2	Purified	Energy production
BioPlan	0.1	Unpurified	Energy production
Trondheim Municipal Energy	0.3	Unpurified	Energy production
Oslo Municipal Energy	1.2	Unpurified	Energy production
Total	47.5		

Oslo Municipal Energy (1.2 kt). Of the fish residues, Scanbio in Trondheim utilized in 2005 salmon residue in the amounts of 120–130 kt to produce about 25 kt fish oil. From the data in [11] shown in Fig. 1 we know that over 99% of the by-products from the fish farming industry is being utilized. This amounts to 156 kt of the total 157 kt freshweight of by-products. Furthermore, these data indicate that 97% of the by-products from herring and 40% of cod by-products are used.

4.8. Fossil diesel replacement and CO₂-reduction potential

According to the biodiesel producer Milvenn in Bergen, if the fat is clean and without any water, then one t of fat can produce close to one t biodiesel. Since residual fat normally is contaminated with various materials, and also contains some water, 95–98% is applied as an expected yield. We have used an average biodiesel efficiency of 95% of the fossil diesel efficiency in the calculations.

We have estimated 8.2 kt fat could be collected from grease traps. This fat is not purified and contains water. By applying a yield of 95% this could give 7.8 kt purified animal fat, which could result in 6.4 kt biodiesel. The estimated residual amounts from the other sources fish oil, slaughterhouse and poultry is also shown in the overview in Table 3.

Assuming a 5% increase in fuel consumption, total amount of 121 kt biodiesel from residual animal fat has the potential to replace 115 kt fossil diesel. Combustion of fossil diesel results in the emission of 3.15 kg CO₂ per kg diesel [12]. The 115 kt fossil diesel thus results in the Tank-To-Wheel (TTW) emission of 362 kt CO₂. An additional 11.7% can be attributed to Well-To-Tank (WTW) emissions, as determined by Lundli et al. [13]. The fossil diesel, which could be replaced with the biodiesel from residual animal fat, thus results in WTW emissions of 405 kt CO₂.

Collection, processing, methanol consumption and distribution, connected to biodiesel production and use, imply combustion of fossil fuels, resulting in CO₂ emissions. Thus, as for biofuels in general, there is not a 100% reduction in CO₂ emissions by replacing fossil fuel use with this type of biodiesel. When considering what the fat from grease traps, slaughterhouses and the poultry industry is used for today, it is however difficult to make a reasonable estimate of the CO₂ reduction potential of these biodiesel sources all together. Detailed WTW studies covering the various methods for processing of this waste fat are needed for this. But we can base us on some earlier studies. Greenhouse gas emissions (GHG) of biodiesel from recycled vegetable oils have been reported to be

Table 3 – Residual fat sources considered and their biodiesel potentials.

Source	Amount residue (kt)	Amount biodiesel (kt)
Collected from grease traps	8.2	6.4
By-products of fish	100.0	92.0
Slaughterhouse and poultry	24.0	22.1
Total	132.2	120.5

16 % of conventional (fossil) diesel emissions, according to Hamelinck et al. [14]. Only esterification and distribution are assumed to cause GHG here. DTI (2003) reports the corresponding WTW figure of 17 % [15], while Beer et al. reports the value for biodiesel from tallow to 24 % [16]. CONCAWE/EUCAR/JRC (2010) applies 12 % as typical for residual animal and vegetable oil together [17]. Based on these studies we have assumed a figure of 20 % of fossil diesels WTW CO₂-emissions for biodiesel produced from residual animal fat.

4.9. Calculation A – new biodiesel production from residual animal fat

It is of interest to estimate the CO₂-reduction from new biodiesel production from residual animal fat. So, if we consider the total potential amount of biodiesel (Table 3) of 121 kt, and subtract the 22 kt utilized by Estra in their biodiesel production, the result is 99 kt biodiesel. This could replace 93 kt fossil diesel. Instead of the 327 kt WTW CO₂ emissions from this amount of fossil diesel there would be emitted 70 kt WTW CO₂ from the 99 kt biodiesel. Thus a reduction of 258 kt CO₂ could be expected from using biodiesel produced from residual animal fat.

4.10. Calculation B – new bioenergy production in the form of biodiesel from residual animal fat

If we subtract the total amounts residual animal fat currently being used for energy production, we can get an estimate for the CO₂-reduction from new bioenergy production in the form of biodiesel from residual animal fat. The amount currently being used for energy production is shown in Table 2. The total potential amount of biodiesel of 121 kt, minus the 48 kt in Table 2 gives us 73 kt biodiesel. This could replace 69 kt fossil diesel. Instead of the 244 kt WTW CO₂ emissions from this fossil diesel there would be emitted 51 kt CO₂ WTW emissions from the 73 kt of biodiesel. Thus a reduction of 193 kt CO₂ could be expected from new bioenergy production in the form of biodiesel from residual animal fat.

4.11. Calculation C – maximum (incl. dumped fish residue)

An additional potential source is the fish residue that currently is being dumped at sea. Although the major part of this, the 450 kt dumped from the fishing vessels, is less likely to be utilized for biodiesel production, due to logistics obstacles, we still can carry out the calculation and consider the amount in the maximum potential. In doing this, we consider the more than 900 kt by-products from all Norwegian fish harvest, with the potential amount of fish fat and oil of close to 200 kt. About 50% of this, or 100kt, is assumed dumped. This amount could produce an additional 95 kt biodiesel. Adding this to the 75 kt above, gives a total of 170 kt biodiesel. This could replace the use of 162 kt fossil diesel. Instead of the 568 kt CO₂ WTW emission from this fossil diesel we would get the WTW emission of 120 kt CO₂ from the 170 kt biodiesel, implying a reduction of 449 kt CO₂.

The results of the calculations of the fossil diesel replacement and CO₂-reduction potentials are summarized in Table 4.

5. Discussion and conclusions

A total of 2200 kt fossil diesel was consumed in Norway in 2006, according to the Norwegian Petroleum Industry Association [18]. This encompasses diesel for use in motorized engines as well as in stationary equipment, excluding maritime use. Realizing the maximum potential will thus replace about 7 % of the total fossil diesel consumption in Norway. The more conservative potential of new biodiesel production will replace 4 %.

The maximum potential of 162 kt biodiesel from used animal fat in Norway is 35 kg per inhabitant. If this factor is applied to all EU-25 with about 460 million inhabitants, the result is 16200 kt biodiesel. This is almost 3 times the estimate by the European Biodiesel Board for the 2006 biodiesel production capacity, of 6100 kt for EU-25 [19]. The lower potential, limited to new biodiesel production, is for 99 kt of biodiesel, or 22 kg per inhabitant in Norway. Applied to EU-25, as above, this could give 9900 kt biodiesel. Although the estimate for Norway on average biodiesel production per inhabitant is not directly applicable to EU-25, due to the relatively large fishing industry in Norway, we still can conclude that:

- Norway is in a good position for producing large amounts of biodiesel from animal and fish residues.

It is however worth keeping in mind that the estimates for potentials from grease traps per inhabitants in Bergen, Oslo and Trondheim probably are too high to be representative for Norway as whole. Residual fat clogging up waste water pipes is a problem mainly for urban areas, with their high population densities. This implies that the density of grease traps per inhabitant probably is less in rural areas, than in the three largest cities of Norway. The magnitude of this error is however assessed to not significantly change the main conclusion above.

This residue based production potential is contrasting the low potentials for producing biodiesel based on utilization of virgin oil from rape seed grown in Norway. We have previously assessed this amount (of rape seed-based biodiesel, RME) that can be produced from rape cultivated in Norway [2]. Production potentials in three different scenarios for future agricultural systems were determined. Due to climatic and

Table 4 – Fossil diesel replacement and CO₂-reduction potentials.

Potential	Fossil diesel that can be replaced (kt)	CO ₂ -reduction (kt)
New biodiesel	93	258
New bioenergy	69	193
Maximum (incl. dumped fish residue)	162	449

environmental limitations, it is only within the scenario of a high-technological intensive agricultural system that it is possible for biodiesel to replace a substantial amount (108 kt) of the fossil diesel consumption in heavy-duty vehicles. Major environmental barriers are however connected to this scenario [20]. Problems from the application of genetic engineering, large use of chemicals and artificial fertilizers are some examples. A fossil fuel replacement of only 22 kt in Norway was considered possible in an environmentally sound agricultural system, such as in organic farming.

It is worth noting that in the analysis of biodiesel potential a Norwegian national perspective was chosen. In principle, much larger amounts of biodiesel could be produced in other countries, where climate and agricultural conditions are more favorable, e.g. in Germany, and imported for use in Norway. However, transporting alternative fuels over long distances, such as currently being done with fossil fuels, is not a favored solution. The national perspective is based in an environmental discourse, with to a large extent agreement that future energy forms must be environmentally sound. In addition, the recent global discussion of energy versus food production on agricultural land has made further major production expansions even more problematic.

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