Feasibility study of the profitability of new bioenergy harvesting machinery from a farmer and agricultural machine company perspective

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March 2016

BIOVALUE SPIR

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Introduction

The entire supply chain must be profitable for the bioenergy industry in order to experience sustainable growth in the long term. Currently the machinery used to harvest and process wheat and cereal straw, rape seed straw, maize straw, and grass silage has been developed and optimized to supply food for livestock and humans. It may be possible to optimize some of the field operations for harvesting the biomass feed stocks for the biogas plants and biorefineries. This feasibility study will investigate the profitability of the current harvesting operations in regards to the suppliers, farmers, of wheat and cereal straw, rape straw, maize straw, and grass silage. It also investigates if agricultural machine companies can cover their expenses when developing new harvesting technologies for the bioenergy market based on the profitability of the current system.

This study first shortly describes the current harvesting processes in Denmark for wheat and cereal straw, rape seed straw, maize straw, and grass silage, then analyzes the profitability of the supplier of the biomass, and finally analyzes if it may be profitable for the agricultural machine company to invest in new harvesting technologies. This is a partial cost calculation which does not cover the profitability of the bio-plants and their operations.

Wheat and cereal straw

In 2014, cereals were grown on 55% of Denmark's total arable land, with wheat comprising 45% of all cereals grown.[i] In 2013, 4.145.200 tons of wheat was harvested, amounting to a total of 3.038.000 tons of cereal straw.[ii] In Denmark, straw is used for both farm and industrial purposes. On the farm, straw is used for bedding, animal feed, and is tilled back into the soil. [iii] For industrial purposes, straw is used to produce electricity and heat (burning and digestion), bio-ethanol, and building materials, such as insulation[iv]. In the future, straw could be used for a variety of high value products like packaging and lipstick.[v] In 2013, according to Danmarks Statistik, 2.136.300 tons of cereal straw was not used or tilled back into the soil.[vi] Not all of this cereal straw is available for use as some is needed to be tilled back into the soil in order to produce humus and maintain the quality of the soil.

Harvesting straw

For cereal grains, the conventional harvest system uses a direct straight combine that cuts, thrashes, separates and cleans the grain.[vii] The chaff and straw can either be spread onto the field or collected for bedding, fodder or feedstock for the bio-industry. If there has been rain after the harvest of the grain, the windrows can either be turned or tedded and raked.

Rapeseed straw

In 2014, 10% of Denmark's arable land was used for cultivating rapeseed for a total of 712.000 tons kg of harvested rapeseed.[viii] Rapeseed straw in Denmark is used for burning and feed but 80% (494.000 tons) of rapeseed straw was not used in 2013.[ix] Rapeseed straw is currently not used to the degree that cereal straw is used, but projects have researched the use of rapeseed straw for bio-ethanol production[xxixii], bio-oil[xiii] and its absorption capacity.[xiv]

	2013
Total straw	619.000
For burning	9.000
For feed	2.000
For bedding, etc.	32.000
Not used	494.000

Table 1: Rapeseed straw in Denmark (tons)[xv]

Harvesting rapeseed

In Denmark, rapeseed can either be harvested by a direct combine if the oilseed is consistent in maturity, or, if the oilseed is inconsistent in maturity, first cut and windrowed, left to ripen on the ground, then collected and processed with a combine harvester.[xvi] The process for harvesting cereal straw and rapeseed straw is the same.[xvii] After the combine harvester processes the rapeseed plant, the straw is usually spread on the ground, but can be placed in windrows and baled.

Permanent grassland grass

In 2014, 20% of Denmaks arable land was used for grass and clover in rotation, grass and green fodder in rotation, total permanent grass land out of rotation, set aside with grass, and fallow land. [xviii]
1.637.700 tons grass or grass and clover were harvested in 2013.[xix] Hay is mostly used for animal feed but can also be used for burning and biogas production. In a biogas study on meadow grass on the island of Fussingø, with the application of potassium vinasse, it was possible to have a net energy balance similar to maize.[xx]

	2013	2014
Grass and clover in rotation	320.000	312.000
Permanent grass land out of rotation	195.000	200.000
Set aside with grass	9.000	6.000
Fallow land	17.000	16.000
Total agricultural area	2.628.000	2.621.000

Table 2: Hectares of grassland in Denmark[xxi]

Harvesting Grass

If the hay is to be stored, harvesting hay starts with cutting and conditioning the grass, then tedding, and raking.[xxii] The collection of the hay is either done by forage harvester or baler. The bales can either be unwrapped or wrapped in plastic.

If the hay is to be used directly after cutting as fodder, either as a biogas feedstock or for animal feed, the hay is cut then chopped by a forage harvester and collected in a wagon.

Harvesting hay from meadow areas in Denmark is either done with a ski-groomer[xxiii] or tractor. The ski-groomer can be used on wetlands and other areas where it is necessary to minimize the damage to nature as much as possible. The belts are replaced with wider belts to reduce the compaction and impact of the treads on the roots of the grass and plants.[xxiv] The ski-groomer is equipped with a mower and the grass is either transported directly into a wagon or baled to minimize the number of passes.

Maize straw

In 2013, 10.100 hectares of matured maize and 180.900 hectares of maize for ensiling were grown in Denmark. Maize is one of the most versatile plants with over 400 different uses ranging from animal feed to fuel, shoe polish and baking ingredients.[xxv] In 2013, 58.200 tons maize straw was not used in Denmark.[xxvi] According to Energistyrelsen, 27.137 tons of maize was used in biogas plants in Denmark in 2013,[xxvii] although it is unlikely this is the total amount since Danish farmers are selling maize to German biogas plants.[xxviii] In 2015, there will be restrictions imposed limiting the quantity of energy crops including maize and sugar beets that can be used at biogas plants in Denmark.[xxix]

Harvesting maize

Maize is harvested with a combine harvester with a different cutter bar than for cereals which separates the kernels from the cob or the cob from the plant and the maize straw is either spread on the field or used as animal feed or bedding.[xxx] When harvesting maize silage for animal feed, either the whole plant or just the ear is cut or picked and chopped with a forage harvester, then collected in a wagon and ensiled for later use.

There is an increasing interest in collecting the maize straw and increasing the harvest efficiency for biomass harvesting operations in the USA which is driven by the bio-ethanol industry. A one-pass prototype biomass harvesting system was tested in Iowa combining a combine and square baler.[xxxi] Another single-pass maize grain and straw baler was developed and tested with several configurations in Wisconsin.[xxxii] As these technologies are new, they have yet to reach Denmark, although in some places the chopped maize straw is being raked and baled from the fields.[xxxiii]

The dry matter content of maize straw is only 50%[xxxiv] and field conditions at the time of harvest in Denmark make field drying unfeasible. Unless the maize straw is to be used immediately by the bio-plant, it is necessary to either store the silage in a silo or wrap the bales in plastic.[xxxv]

Profitability of harvesting straw and hay for biomass

This section investigates the profitability of harvesting straw and hay for feedstock based on current prices in 2013. The profitability of harvesting straw, rapeseed straw, maize straw and grass for biomass was found by calculating the gross income from the yields minus the harvesting and logistic expenses. To simplify the variables, this is a partial cost calculation only covering the harvesting processes and not the entire process chain. All other operations are assumed to be covered by the grain or maize.
It is necessary to mention that the figures used in the calculations are averages from various sources and may vary from actual farm conditions depending on weather, field size and shape, machinery used, wages, etc.

Gross income

The gross income was calculated from the tons of dry matter (DM) per hectare from 2013 and the price per ton of DM that the biogas plant would pay.[xxxvi] If the information for the DM per hectare was not found, it was instead calculated using the total yield[xxxvii] (tons per ha) and the DM percentage.[xxxviii] All figures have been rounded down.

Crop yields – t DM/ha	**Min**	**Max**	**Average**
Straw[xxxix]	3,4	4,6	
Rapeseed straw (3,5 t/ha[xl] * 85% DM[xli])			2,98
Maize straw (4,7 t/ha[xlii] * 50% DM[xliii])			2,35
Grass silage[xliv]	9,1	10,8	
Meadow grass (min/max[xlv] and average[xlvi])	1	9	3

Table 3: Dry matter crop yields and DM calculations

It is assumed that the bio-plant pays for the feedstock and does not grow the feedstock themselves.

Biomass from 1 ha	**Min (DKK)**	**Max (DKK)**	**Average (DKK)**
Straw	2 000	2 700	2 300
Rapeseed straw			1 300
Maize straw			1 300
Grass silage	6 500	12 900	9 700
Meadow grass	1 600	500	4 900

Table 4: Gross income from 1 ha dry matter from 2013

Expenses

To find the harvesting expenses, the costs per hectare were calculated for each of the harvesting processes.[xlvii] A large baler was used as this size of bales is used by most bio-plants in Denmark.[xlviii] To simplify the calculations, a 18m tedder and rake was used. All wages have been calculated into the machine expenses.

In the logistics calculations it is assumed that that the distance from the field to the storage and back is 5 km. The expenses of plowing, seedbed preparation, seed drilling, fertilizing, spraying, and combine harvesting are assumed to be covered by the sale of the crop.

Grain straw harvesting costs	**Dry weather DKK/ha**	**Rainy weather DKK/ha**
18m tedder		150
18 m rake		150
Large bales	514	514
Loading wagon with bales and wagon	105	105
Transportation from field to storage	111	111
Unloading and loading into storage	82	82
Harvesting costs	**813**	**1113**

Table 5: Costs for harvesting grain straw

The expenses for collecting rapeseed straw are baling and logistics. The expenses of plowing, seedbed preparation, seed drilling, fertilizing, spraying, and combine harvesting are assumed to be covered by the sale of the rape seed.

Rape seed straw harvesting costs	**Dry weather DKK/ha**	**Rainy weather DKK/ha**
18m tedder		150
18 m rake		150
Large bales	499	499
Loading wagon with bales and wagon	106	106
Transportation from field to storage	108	108
Unloading and loading into storage	21	21
Harvesting rapeseed straw - DKK per ha	**733**	**1033**

Table 6: Costs for harvesting rapeseed

The expenses for collecting the maize straw are baling and logistics. It is assumed that the maize is processed by a combine harvester and the maize straw is left on the ground in a swath. Because maize is usually harvested in late autumn, it is not possible to dry the maize straw in the field. The moisture problem can be solved by putting the maize straw in the bio-plant right after harvest, wrapping the bales in plastic, storing in an air-tight silo, or drying the straw. The storage and drying options have not been calculated.

Maize straw harvesting costs	Large bales & logistics DKK/ha	Medium wrapped bales & logistics DKK/ha	Forage harvesting & logistics DKK/ha
Tedder	150	150	150
Rake	150	150	150
Large bales	676		
Medium bales wrapped in plastic		2 473	
Forage harvesting, transportation, move to storage			575
Loading wagon with bales and wagon	144	144	
Transportation from field to storage	147	200	
Unloading and loading into storage	108	108	
Total expenses - Rain – DKK/ha	**1 373**	**3 223**	**875**
Total expenses - Dry – DKK/ha	**1 073**	**2 923**	**575**

Table 7: Costs for harvesting maize straw

There are many methods of growing and producing hay. For simplification, it is assumed that the permanent grassland is seeded every other year and cut twice a year with no grazing. Two harvesting methods based on storage options have been calculated – forage harvesting and baling. The expenses for forage harvesting are seeding, fertilizing, tedding, raking, mowing, forage harvesting and logistics. The expenses for baling are seeding, fertilizing, mowing, tedding, raking, baling, and logistics. Storage options have not been calculated, but it is more expensive to store grass in a silo than in a bale.[xlix]

Permanent grass harvesting costs	Forage Harvest costs (2 cuts)	Baling costs (2 cuts)
Grass seed (once every 2 years) - DKK per ha	390	390
Fertilizer - Nitrogen	2 100	2 100
Fertilizer - Phosphorus	588	588
Fertilizer - Potassium	2 138	2 138
Plastic	399	399
Fertilizer spreader	280	280
Seeder	88	88
Mower	500	500
Tedding	300	300
Raking	300	300
Forage harvester, transportation, move to storage	1 150	
Large bales		1 300
Loading wagon with bales and wagon		773
Transportation from field to storage		818
Unloading and loading into storage		555
Total expenses	**8 233**	**10 509**

Table 8: Costs for harvesting permanent grass

For calculating the harvesting expenses for meadow grass, the ski-groomer case was used. If a tractor was used, the expenses would likely be close to the permanent grassland expense calculations in table 8 without the seeding, fertilizer, and plastic costs. The ski-groomer calculation does not include the transportation of the bales out of the field, as some of the ski-groomers load the bales while cutting the grass.

Meadow grass may have an average of dry matter (DM) of 3 t DM/ha[l]. The range is from 1 to 9 t DM/ha for harvesting meadow grass[li]. The amount of DM collected impacts how many bales are produced.

Costs – 1 cut	Min	Max
Ski groomer with mower	3 579	3 579
Large bales (based on DM collected)	143	1 286
Total costs	**3 722**	**5 007**

Table 9: Costs for harvesting meadow grass with a ski-groomer

When using a tractor instead of a ski-groomer, the machine costs for 1 cut of baled meadow hay is 2 263 DKK and machine costs for 1 cut of forage harvested meadow grass is 1 125 DKK.

Profit

The profit has been calculated by subtracting the expenses from the gross income. All amounts have been rounded down. These amounts are likely to differ from actual results, but do give an approximate indication of what is possible.

Biomass harvesting profits	Min (DKK per ha)	Max (DKK per ha)	Average (DKK per ha)
Straw – rainy weather	800	1 600	1 200
Straw – dry weather	1 100	1 900	1 500
Rapeseed straw			600
Maize straw – forage harvester – rainy weather			500
Maize straw – forage harvester – dry weather			800
Maize straw – large bales – rainy weather			10
Maize straw – large bales – dry weather			300
Maize straw – small wrapped bales – rainy weather			-1 800
Maize straw – small wrapped bales – dry weather			-1 500
Grass silage – forage harvester - 2 cuts	-1 700	4 700	1 500
Grass silage – large bales – 2 cuts	-4 000	2 400	-700
Meadow grass – large bales – 1 cut	-3 200	-60	-2 800

Table 10: Profit from biomass from 1 ha

Straw, rapeseed straw, forage harvested maize straw, and forage harvested grass silage are the most profitable. Results for maize straw vary depending on the type of harvesting method used. Forage harvested maize straw is the most profitable but storing chopped crops is more expensive than storing bales. Grass silage varies from unprofitable to profitable depending on the amount of dry matter. Meadow grass is unprofitable unless the municipality pays the farmer or contractor to cut the meadow grass (this is usually done to increase biodiversity).

Farmer profitability

Current harvesting machinery was developed and optimized to supply food and feed. It may be possible to optimize some of the field operations for the supply of biomass feed stocks for biogas plants and bio-refineries. To warrant the development of such machinery, it is necessary to evaluate whether it may be profitable for farmers to prefer equipment optimized for biomass when buying new equipment.

To indicate the range of possibilities, it is assumed that the price of the biomass-optimized machines will be comparable to the current machines. The calculations in table 11 are based on rounded down average profits from table 10.

Biomass	Profit (DKK) from 50 ha	Profit (DKK) from 200 ha	Profit (DKK) from 400 ha	Profit (DKK) from 1.000 ha
Straw – rainy weather	44.000	178.000	357.000	893.000
Straw – dry weather	59.000	238.000	477.000	1.193.000
Rapeseed straw	30.000	121.000	242.000	605.000
Maize straw – large bales	8.000	32.000	65.000	163.000
Maize straw – forage harvester	33.000	132.000	264.000	661.000
Grass – forage harvester (2 cuts)	76.000	304.000	609.000	1.523.000

Table 11: Profit from the biomass harvested from various size farms

The profits will vary greatly depending on how much of the biomass is sold to the bio-plant instead of used on the farm. Straw and rapeseed straw are the most profitable whereas maize straw and grass are currently mostly unprofitable.

The affordability of a machine is best illustrated by its payback time. Each farmer will require a different payback time depending on their finances and circumstances. All payback calculations are rounded up to the nearest year.

	Average prices 2013 (DKK)[lii]	Payback from average profit from 200 ha (Years)				Payback from profit from 1.000 ha (Years)			
		Straw	Rape seed	Maize	Grass	Straw	Rape seed	Maize	Grass
Combine harvesters	2 316 667	12	20	29	8	3	3	6	
Large balers	900 000	5	8	11	3	1	2	3	1
Mowers	412 500	2	4	6	2	1	1	2	1
Tedders	191 667	1	2	3	1	1	1	1	1
Rakes	350 000	2	3	5	2	1	1	1	1
Self-propelled forage harvesters	2 500 000			31	9	3	5	7	7

Table 12: Average prices of machines in Denmark in 2013 and the average payback based on the profit

The payback is calculated for the average profits on just straw and hay sold for biomass. Interest has not been taken into account.

Grain straw and rapeseed straw generally have acceptable payback times for both 200 and 1 000 ha farm sizes except for the combine harvester. (This machine is of course indispensable anyway for the purposes of harvesting the crop.) Maize straw generally does not have an acceptable payback for farms 200 ha and smaller and would be difficult with the current technologies to make a profit.

In conclusion, these average numbers show that harvesting biomass will contribute significantly to the profitability of machinery.

Agricultural machine company profitability

To determine if it is profitable for an agricultural machine company to invest in technologies for harvesting biomass for bio-plants, calculations were made for the market size, current average price for the machines in Denmark, cost of development project, and payback of development project. These calculations give an impression of whether or not developing new harvesting technologies is profitable for the individual agricultural machine company.

Market size

Two approaches were used for the market size in Denmark, actual number of units sold from VDMA and how many machines were used up in 2013. By knowing the market size and the agricultural machine's market share, the total number of units sold can be forecasted along with the price of the machine. This can give the agricultural machine company an idea if it is interesting to invest in new harvesting technologies.

To calculate how many machines were used up and thus needed to be replaced, the average lifetime[liii] of the machine in hectares was calculated and divided by the total number of hectares a given machine harvested in 2013. It is assumed that the machines are scrapped when their lifetime is used up.

Machine	**Machines used up in 2013 in DK**					**Actual number of units sold in 2013 in DK**[liv]
	Straw	Rape seed straw	Maize straw	Grass	Total	
Combine harvesters	276	34	2		312	238
Large balers All balers	268	33	2	40	303	65 129
Mowers				25	25	678
Tedders				23	23	354
Rakes				19	19	34
Self-loading forage harvesters				11	11	
Self-propelled forage harvesters						25

Table 13: Market size based on units sold and used up in Denmark in 2013

	Average prices in 2013 (DKK)[lv]	**Total average market size based on used up machines from 2013**	**Total average market size based on sold machines from 2013**
Combine harvesters	2 317 000	722 800 000	551 367 000
Large balers	900 000	272 700 000	116 100 000
Mowers	413 000	10 313 000	279 675 000
Tedders	192 000	4 409 000	67 850 000
Rakes	350 000	6 650 000	11 900 000
Self-loading forage harvesters			
Self-propelled forage harvesters	2 500 000		62 500 000

Table 14: Average market size in DKK based on used up machines and actual sold machines in 2013

If an agricultural machine company had a 10% market share in Denmark, for combine harvesters, they would be able to sell between 23 and 31 units with a turnover of approximately 55 and 71 million Danish kroner. Since all major agricultural machines in Europe sell in more than just the Danish market, the total forecast is likely to be far larger.

Development project costs and sensitivity analysis

To discover if a development project for new biomass harvesting technologies will be profitable for an agricultural machine company, the total project budget, net present value (NPV), required rate of return (RRR), internal rate of return (IRR), and payback have been calculated or estimated.

Since the average prices of the machines are known and the markup values from the distributor and machine producer are unknown, the net cash flow has been calculated backwards by estimating the distributors mark up and the desired net profit, and total project cost. The net sales were then multiplied by the units sold each year to find the net cash flow. It is assumed that the same amount of units are sold each year and the price does not change.

For the sensitivity analysis, the project cost was adjusted until the IRR was between 45-47% in order to see how much a project could cost if 100 or 150 units were sold in order to be able to find the maximum value that the company could afford and still be profitable. An IRR of 45-47% was chosen because the development of new technology for the bio-plant market is considered high risk (the market is greatly impacted by the changing legislation).

The new harvesting technology can be profitable, but it will be very dependent on the individual agricultural machine company's variable costs, fixed costs, contribution margin, depreciation, project cost and the actual required rate of return. Since the total market size in Denmark is small, it is unlikely that a single agricultural company will be able to sell 100 units or more in the Danish market alone. However, this is a theoretical problem since companies sell in more than one European market.

Sensitivity analysis	Combine harvester Example 1 (DKK)	Combine harvester Example 2 (DKK)	Baler Example 3 (DKK)	Baler Example 4 (DKK)
Unit sold yearly (same for 4 years)	100	150	100	150
Unit price to farmer	2 317 000	2 317 000	900 000	900 000
Distributor mark up	30%	30%	30%	30%
Profit margin for machine company (distributor price - variable and fixed costs) in percentage	20%	20%	20%	20%
Total project cost	50 000 000	76 000 000	19 500 000	29 000 000
RRR	45%	45%	45%	45%
NPV (4 years)	1 072 000	607 000	341 000	761 000
IRR	47%	46%	46%	47%
Payback	1,7 years	1,7 years	1,7 years	1,7 years

Table 15: Sensitivity analysis - maximum values of what is affordable for a high risk development project

Sensitivity analysis	Mower Example 5(DKK)	Mower Example 6 (DKK)	Tedders/rakes Example 7 (DKK)	Tedders/rakes Example 8 (DKK)
Unit sold yearly (same for 4 years)	100	150	100	150
Unit price to farmer	400 000	400 000	250 000	250 000
Distributor mark up	30%	30%	30%	30%
Profit margin (distributor price - variable and fixed costs) in percentage	20%	20%	20%	20%
Total project cost	8 700 000	13 000 000	5 500 000	8 000 000
RRR	45%	45%	45%	45%
NPV (4 years)	118 000	227 000	11 000	267 000
IRR	46%	47%	47%	47%
Payback	1,7 years	1,7 years	1,7 years	1,7 years

Table 16: Sensitivity analysis - maximum values of what is affordable for a high risk development project

Table 15 and 16 show the correlation between the number of units sold and the cost of the project. The higher the amount of units to be sold, the more the development project can cost. Therefore it is important to choose a bioenergy harvesting technology that can be adapted as widely as possible.

Conclusion

The most profitable crops for harvesting the straw or hay is grain, rapeseed and grass and thus, a development project for bio-plant harvest optimization should be targeted towards these. The larger the farm, the more likely the farmer would be able to cover their costs when buying a new machine. Transportation of the feedstock to the biogas plant may diminish the profit, but generally, it is highly advisable to sell cereal and rapeseed straw as feedstocks to bioenergy and bioplants.

In most cases for Denmark, it is possible for an agricultural machine company to start a development project to optimize harvesting for bio-plant purposes. The only crop that is unadvisable to start a development project is for maize straw as it will be difficult for a farmer to buy a new machine from the profits of maize straw. It is important that the forecasted number of units sold can be sold when the project ends otherwise the development project may cost more than is recoverable.

References

[i] Danmarks Statistik, http://www.dst.dk, Det dyrkede areal efter område, enhed, afgrøde og tid
[ii] Danmarks Statistik, http://www.dst.dk, Høstresultat efter afgrøde og enhed
[iii] http://www.denstoredanske.dk/Natur_og_milj%C3%B8/Landbrug_og_havebrug/Korn_og_b%C3%A6lgs%C3%A6d/halm
[iv] http://www.bolius.dk/halm-som-isolering-18612/
[v] http://fvm.dk/nyheder/nyhed/nyhed/halm-skal-forvandles-til-braendstof-emballage-og-laebestift/
[vi] Danmarks Statistik, http://www.statistikbanken.dk/HALM1, Halmudbytte og halmanvendelse efter område, afgrøde, enhed og anvendelse
[vii] http://extension.oregonstate.edu/sorec/sites/default/files/wheat_harvest_drying-storage.pdf
[viii] http://www.dst.dk/pukora/epub/Nyt/2014/NR593.pdf
[ix] Danmarks Statistik, http://www.statistikbanken.dk/HALM1, Halmudbytte og halmanvendelse efter område, afgrøde, enhed og anvendelse
[x] http://www.sciencedirect.com/science/article/pii/S0960852413018737
[xi] http://www.sciencedirect.com/science/article/pii/S0961953411006593
[xii] http://www.sciencedirect.com/science/article/pii/S0960852411009199
[xiii] http://www.sciencedirect.com/science/article/pii/S0165237013002854
[xiv] http://www.sciencedirect.com/science/article/pii/S0960852412013235
[xv] Danmarks Statistik, http://www.dst.dk, Halmudbytte og halmanvendelse efter område, afgrøde, enhed og anvendelse
[xvi] https://www.landbrugsinfo.dk/Planteavl/Afgroeder/Olieplanter/Vinterraps/Sider/pl_pn_11_386.aspx
[xvii] https://www.landbrugsinfo.dk/Energi/Biogas/Sider/Harvest-methods-capacities-and-cost_pl_14_1999.aspx
[xviii] Danmarks Statistik, http://www.dst.dk, Det dyrkede areal efter område, enhed, afgrøde og tid
[xix] Danmarks Statistik, http://www.dst.dk, Det dyrkede areal efter område, enhed, afgrøde og tid
[xx] http://orgprints.org/14415/3/14415.pdf
[xxi] Danmarks Statistik, http://www.dst.dk, Det dyrkede areal efter område, enhed, afgrøde og tid
[xxii] http://fyi.uwex.edu/agrability/files/2010/02/HayHandlingTipSheet1a.pdf
[xxiii] http://www.dagens.dk/teknologi/tysk-pistemaskine-ombygges-til-dansk-naturplejemaskine
[xxiv] http://natur-biomasse.dk/biomasse/enggraes/
[xxv] http://www.kycorn.org/documents/cornuses.pdf
[xxvi] Danmarks Statistik, http://www.dst.dk, Halmudbytte og halmanvendelse efter område, afgrøde, enhed og anvendelse
[xxvii] http://www.ens.dk/sites/ens.dk/files/undergrund-forsyning/vedvarende-energi/bioenergi/biogas/biogasproduktion_2012_og_e-afgr_2012-2013.xlsx
[xxviii] http://www.information.dk/319499
[xxix] http://ing.dk/artikel/kronik-politikerne-goer-livet-surt-biogassen-171062
[xxx] http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1393&context=etd page 2
[xxxi] http://farmprogress.com/story-agco-to-demonstrate-biomass-harvesting-system-9-32536
[xxxii] http://agriculturalmachineryengineering.weebly.com/uploads/9/0/5/7/9057090/asabepaper121337628.pdf
[xxxiii] https://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Gas/Opg%C3%B8relse%20over%20alternative%20biomasser%20til%20biogas%20i%20Ringk%C3%B8bing-Skjern%20Kommune.pdf

[xxxiv] https://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Gas/Opg%C3%B8relse%20over%20alternative%20biomasser%20til%20biogas%20i%20Ringk%C3%B8bing-Skjern%20Kommune.pdf
[xxxv] https://www.landbrugsinfo.dk/Energi/Biogas/Sider/Harvest-methods-capacities-and-cost_pl_14_1999.aspx
[xxxvi] http://www.ens.dk/sites/ens.dk/files/undergrund-forsyning/vedvarende-energi/bioenergi/biogas-taskforce/biomasse_til_biogasanlaeg_endelig_version3_2_0.pdf
[xxxvii] http://www.statistikbanken.dk/HALM1
[xxxviii] https://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Gas/Opg%C3%B8relse%20over%20alternative%20biomasser%20til%20biogas%20i%20Ringk%C3%B8bing-Skjern%20Kommune.pdf
[xxxix] http://www.biopress.dk/PDF/FiB_41-2012_05.pdf
[xl] http://www.statistikbanken.dk/HALM1
[xli] https://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Gas/Opg%C3%B8relse%20over%20alternative%20biomasser%20til%20biogas%20i%20Ringk%C3%B8bing-Skjern%20Kommune.pdf
[xlii] http://www.statistikbanken.dk/HALM1
[xliii] https://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Gas/Opg%C3%B8relse%20over%20alternative%20biomasser%20til%20biogas%20i%20Ringk%C3%B8bing-Skjern%20Kommune.pdf
[xliv] http://www.sciencedirect.com/science/article/pii/S0961953414001421
[xlv] http://agro-technology-atlas.eu/docs/ekstrudering_poul_erik_l%C3%A6rke.pdf
[xlvi] http://dlgtele.dk/media/4944/12%20DLF-Trifolium.pdf
[xlvii] VFL and https://farmtalonline.dlbr.dk
[xlviii] http://www.videncenter.dk/gule%20halm%20haefte/Gul_Dansk/halm-DK04.pdf
[xlix] VFL - Lone
[l] http://agro-technology-atlas.eu/docs/ekstrudering_poul_erik_l%C3%A6rke.pdf
[li] http://dlgtele.dk/media/4944/12%20DLF-Trifolium.pdf
[lii] https://farmtalonline.dlbr.dk
[liii] https://farmtalonline.dlbr.dk/
[liv] http://www.vdma.org/
[lv] https://farmtalonline.dlbr.dk