Greenhouse gas emission analysis

of an Egyptian rice straw biomass-to-energy chain

Project: Technical and economic feasibility of environmentally safe rice straw disposal and utilisation methods for Egypt

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Content

Introduction

A common practice in Egypt has been the burning of rice straw, as a measure to prepare agricultural land for follow-up crops. This practice has caused significant greenhouse gas emissions, in addition to aerial pollution. By using straw residue for the production of pellets and shipping these pellets to Europe for co-firing in electricity plants, significant overall emission reductions could be achieved.

This study was conducted in the framework of project “Technical and economic feasibility of environmentally safe rice straw disposal and utilization methods for Egypt”. Based on a potential business set-up with three pelletizers, divided over three rice producing regions in Egypt’s Nile Delta, greenhouse gas emissions were quantified for the principal operations in the biomass-to-energy chain. Also expected emission reductions were calculated, in comparison with the use of fossil fuels.

The greenhouse gas emissions and savings calculations are based on the methodology used by the European Commission, as documented in the Renewable Energy Directive (2009) and the Dutch NTA 8080 standard for bio-energy chains. Results are analyzed for compliance with these standards’ minimum requirements for greenhouse gas emission reductions. The level of compliance may be indicative for the potential of (future) certification of rice straw pellet operations in Egypt, as a mechanism for improved access to European markets.

Calculations were performed with a specially developed Excel tool and are based on multiple international sources of literature on greenhouse gas emissions.

Chapter 1 explains the calculations and GHG emission outcomes for five emission factors based on the Renewable Energy Directive. Chapter 2 calculates the realized GHG emission savings, comparing total emissions from production and use of rice straw pellets with use of fossil coal. Two annexes include a flow-chart of the rice straw chain and an overview of the Excel tool used for the GHG calculations, respectively. Finally, conclusions are drawn regarding compliance with RED and NTA 8080 emission savings requirements and need for further research on GHG calculation methodologies.

1 Greenhouse gas emission calculations

1.1 General chain description

The analysis is based on rice straw production in three regions of Egypt: Kafr el Sheikh, Dakahlia and Sharkia. Here, farmers produce rice straw as by-product of rice grain cultivation and may burn it on their fields or sell it to traders (Steele et al, 2009). Given its status as "residue", according to RED (2009), the cultivation and mowing of rice straw is not included in the overall greenhouse gas emission calculations.

It is assumed that traders buy the rice straw from farmers and bale it on their land prior to transport. With or without temporary storage, the bales are transported to pelletizing plants in the region by truck. These pellet plants are strategically located, at a distance not exceeding 60 kilometres. The pellet plants combine a number of processes, including dirt removal, straw milling, pelletizing, air cooling and pellet transport for silo storage by conveyer belt (Welhuis, 2010). Emission calculations are based on use of diesel and electricity, by tractor-powered baling machines, trucks and pellet plants respectively. Any differences between type (e.g. round or rectangular), size and weight of straw bales are not taken into consideration.

The pellets are dumped from silos into containers and transported by truck to the port of Alexandria. Here, the pellets are either stored or the containers are directly loaded onto container vessels of the PANAMAX type, that have a maximum pay load capacity of 5000 TEU or 80.000 tons of bulk (Schmied *et al*, 2010). If available, larger vessels may be considered, including for bulk transport, given the potentially lower emission per Ton*Kilometer (section 1.3.5). Emission calculations are based on diesel use by trucks and ship oil use by the PANAMAX vessels.

The destination for the Egyptian rice straw pellets are electricity plants in or nearby Rotterdam, that use pellets for co-firing. Pellets are used to replace coal, hence emissions of rice straw baling, pelletizing and transport are compared with emissions of coal-fired electricity plant (Chapter 2). Any greenhouse gases emitted after arrival at the port of Rotterdam are not taken into consideration.

Annex 1 visualizes the Egyptian rice straw-to-energy chain, indicating the principal processes and the flows of energy and fuel input and product and emission output.

1.2 Calculation methodology

The greenhouse gas (GHG) emission calculations follow the methodology used in the Renewable Energy Directive by the European Commission (2009). This directive acts as a meta standard for standards to be developed per member state and is included in European legislation. Among other, it contains European agreements on levels of emission reductions and has been included in Dutch legislation, as of December 2010.
In the Netherlands, since January 2011, the NTA 8080 standard has been in effect. It has a similar coverage of sustainability aspects and uses the same methodology for GHG emission calculations. The NTA 8080 differs from the RED in that it is a voluntary standard, also applicable to solid biomass and including specific requirements for companies regarding welfare and wellbeing.

Organizations anywhere in the world, involved in production, processing, transport and use of biomass for energy purposes, now can choose to have their operations certified against the NTA 8080 standard. The certificate should prove to customers and the general public that the organization is in compliance with a comprehensive list of sustainability requirements. This includes requirements for greenhouse gas emission savings assessed in this study. Both the RED and NTA

8080 standards dictate minimum net emission savings obtained from the biomass operations, as compared to use of fossil fuels. These requirements are prescribed for three reference situations listed in *Table 2.* For this study, the emission reference for coal-fired power plants is relevant.

The following formula applies for calculating the net GHG emissions throughout the rice straw-to-energy chain:

$$E = E_{EC} + E_{L} + E_{P} + E_{TD} + E_{U} – E_{SCA} – E_{CCS} – E_{CCR} – E_{EE}$$

The calculation factors, as well as their relevance for the project context in Egypt, are explained in *Table 1*.

Table 1: Calculation factors and relevance for the Egyptian rice straw biomass- to- energy chain

Symbol	Description	Relevance for JaLo bio-pellet chain
E	total emissions from the use of the fuel	Expressed in grams of CO_2 equivalent per Mega Joule (MJ) of pellet-generated electricity in a coal-fired electricity plant (gCO_2-e/MJ pellet -e)
E_{EC}	emissions from the extraction or cultivation of raw materials	Includes baling of rice straw
E_{L}	annualized carbon stock changes caused by land use change	Not taken into consideration due to insufficient data availability.
E_{P}	emissions from processing	Includes milling, drying, pelletizing, (air) cooling and pellet transport by conveyer belt to silo.
E_{TD}	emissions from transport and distribution	Separate emission factors are calculated for biomass supply, straw transport to Alexandria and pellet shipment to Rotterdam.
E_{U}	emissions from the fuel in use	Kept at “0” in accordance with Renewable Energy Directive.
E_{SCA}	emission saving from soil carbon accumulation via improved agricultural management	Not taken into consideration due to insufficient data availability.
E_{CCS}	emission saving from carbon capture and geological storage	Not taken into consideration due to insufficient data availability.
E_{CCR}	emissions saving from carbon capture and replacement	Not taken into consideration due to insufficient data availability.
E_{EE}	emission saving from excess electricity from co-generation	Not taken into consideration due to insufficient data availability.

The following formula applies to calculate the greenhouse gas emissions savings from use of biofuels: :

$$(E_F – E_B)/E_F$$

Where E_B = total emissions from the biofuel or bioliquid and E_F = total emissions from the fossil fuel comparator. Savings calculations are further explained in chapter 2.

Table 2: minimum requirements for net GHG emission reductions

Installation	Fossil reference	Minimum requirement net GHG emission reduction
Co-firing in coal fired power plant	Electricity from coal fired power plant	**70%** (this study)
Co-firing in gas fired power plant	Electricity from gas fired power plant	50%
Other systems	Dutch mixture of electricity production (Energy mix)	70%

1.3 Egyptian rice straw biomass-to-energy emissions

Greenhouse gas emissions relate to rice straw baling (E_{EC}), processing of straw into pellets (E_P) and transport and distribution of rice straw bales and pellets (E_{TD}). For E_{TD}, a distinction is made between rice straw supply (E_{TD}-1), pellet transport (E_{TD}-2) to Alexandria and pellet shipment to Rotterdam (E_{TD}-3). Hereafter, emission calculations are explained for all five emission factors. Calculations were performed with an Excel calculation tool specially developed for this study.

1.3.1 Rice straw baling (E_{EC})

Based on a Harvesting Index of 0.4 (Steele et al, 2009), a national rice variety may produce around 6 tons of grain and 9 tons of straw residue per hectare, per year. An assumed 4 tons of rice straw per hectare are available for pelletizing, each year. *Table 3* shows the respective rice cultivation area available in each of the three regions, as well as the tonnage per hectare (Idem). Emission calculations are based on use of a 140 kW tractor and a baler with a capacity of 12800 kilograms per hour, consuming 3,7 liters of diesel per ton straw (Amoasah, 2010). Each liter of diesel has an assumed energy content of 36,55 MJ (RED, 2009). Each MJ is assumed equivalent to 83,8 grams of CO_2 emissions (idem). Both conversions, into Mega Joules (MJ) and kilogram CO_2 emissions, are included in *Table 3.*

Table 3: Energy use rice straw baling

Region	***Hectares***	***Ton.ha^{-1}***	***Liter.Ton^{-1}***	***Liter.year^{-1}***	***MJ.year^{-1}***	***KgCO$_2$.year^{-1}***
Kafr el Sheikh	103870	4	3,7	1566359.6	57250443	4797587
Dakahlia	174590	4	3,7	2632817.2	96229469	8064029
Sharkia	123640	4	3,7	1864491.2	68147153	5710731
Total	402100			6063668	221627065	**18572348**

1.3.2 Rice straw supply to the pelletizer (E_{TD}-1)

Transport emissions depend to a large extent on the average travel distance between supply areas and the pelletizing unit(s). Travel distance estimations start with imagining each region as a circle with a pelletizing unit in the middle. The surface area of the circle represents the number of hectares of a particular region. The transport distance is estimated by calculating the radius *R* of each circle, as in the following formula: πR^2 = Surface area (in Km^2). In reality, however, destinations cannot be reached in a straight line. Therefore, the radius is doubles so as to obtain a more realistic estimation of the average transport distance. For the CO_2 emission calculations, the return distance is taken into account, as transport trucks are not expected to carry a payload on their way back from the pelletizing unit.

A limiting factor is the maximum transport distance to the pelletizing unit of 60 kilometres. Beyond that distance, rice straw pellet production is no longer profitable. However, as *Table 4* shows, this distance is not exceeded in any of the three regions. Hence, 1 pelletizing unit per region suffices.

Table 4: Transport distances in kilometres

Region	***Hectares***	***Ton.ha^{-1}***	***Units***	***Ton.year^{-1}***	***Radius (km)***	***Distance***	***Return distance***
Kafr el Sheikh	103870	4	1	415480	18.19	36.38	72.75
Dakahlia	174590	4	1	698360	23.58	47.16	94.32
Sharkia	123640	4	1	494560	19.84	39.69	79.37
Total	402100		3	1608400			

Road transport emissions are expressed in grams CO_2 emitted for every ton moved over 1 kilometer, in short: gCO_2 per TKM. The calculations in *Table 5* are based on an assumed emission of 221 grams of CO_2 per TKM (Koop *et al*, 2010).

Table 5: Tonnage x kilometer (TKM) and CO_2 emission equivalence

Region	***Ton.year^{-1}***	***Return duistance***	***Tonnage.KM***	***KgCO2.TKM^{-1}***	***Kg CO_2.year^{-1}***
Kafr el Sheikh	415480	72.75	30226674	0.221	6680095
Dakahlia	698360	94.32	65869476	0.221	14557154
Sharkia	494560	79.37	39254880	0.221	8675328
Total	1608400		135351029		**29912577**

1.3.3 Rice straw pelletizing (E_P)

The rice straw is processed in pellet plants that run on electricity. Accordingly, greenhouse gas emissions are calculated on the basis of kilowatt-hours of electricity used. As the average supply distance remains below 60 kilometres, in all three regions 1 pelletizing unit will suffice. Despite differences in production scale, the emissions per ton pellets are assumed to be equal for all three pelletizing units.

Using reference data from a pellet plant in Denmark (Welhuis, 2010), approximately **140** kilowatt-hour of electricity is required to produce 1 ton of pellets. This amount of energy includes milling – to reduce particle size prior to pelletizing – and pellet transport to storage in silos by means of a conveyer belt. During pelletizing, the moisture content is reduced from 12% (straw) to 8% approximately. The biomass tonnage is reduced accordingly, see *table 6*.

In Egypt, most of the electricity is generated with natural gas, the remainder with coal and other fossil fuels (source). The emissions involved in pelletizing are therefore based on assumed comparability with the Dutch *Electricity Production Mix*. Accordingly, emissions are calculated against 0.482 kg CO^2 per kilowatt-hour (kWh) of electricity (Koop *et al,* 2010).

Table 6: Electricity use for pelletizing and corresponding CO^2 emissions

Region	***T straw.year^{-1}***	***T pellet.year^{-1}***	***Units***	***kWh.year^{-1}***	***Kg CO_2.kWh^{-1}***	***Kg CO^2.year^{-1}***
Kafr el Sheikh	415480	400641	1	56089800	0.482	27035284
Dakahlia	698360	673419	1	94278600	0.482	45442285
Sharkia	494560	476897	1	66765600	0.482	32181019
Total	1608400	1550957	3	217134000	0.482	**104658588**

1.3.4 Pellet transport to Alexandria (E_{TD}-2)

As for E_{TD}-1, also for this factor transport emissions are expressed in grams of CO_2 per TKM. *Table 6* provides an overview of TKM calculations and corresponding emissions. Due to assumed lack of return pay-load, calculations are based on the return distance between Alexandria and the sourcing areas. Transport is assumed to take place in 20'' containers, that are loaded directly from silos at the pellet plant. No energy needs for container loading are therefore included. The indicated emissions in Kg CO_2 per TKM are based on trucks weighing 28 tons (Koop *et al*, 2010). Although this weight may be inferior to a truck transporting a fully loaded 20" container, the same reference is used. An additional assumption is that there are no legal restrictions as to maximum allowable truck loads on Egyptian roads.

Table 7: Fuel use for pellet transport to Alexandria and corresponding CO_2 emissions

Region	*T pellet.year^{-1}*	*KM (return)*	*Tonnage.KM*	*Kg CO_2.TKM^{-1}*	*Kg CO_2.year^{-1}*
Kafr el Sheikh	400641	240	96153943	0.221	21250021
Dakahlia	673419	450	303038357	0.221	66971477
Sharkia	476897	350	166914000	0.221	36887994
Total	1550957		566106300		**125109492**

1.3.5 Pellet shipment to Rotterdam (E_{TD}-3)

Any number of chartered PANAMAX vessels is dependent upon the amount of pellets produced and the combined number of days required for return port-to-port travel, loading and unloading. Based on a pellet production of 10.812 tons per day (300 working days) and an average travel duration of 22 days (Schmied *et al*, 2010), three 80.000 ton PANAMAX vessels are required. In this favourable logistical set-up, the maximum load capacity per vessel can be approximated, with 79291 tons loaded on each vessel. This is equivalent to 3674 fully loaded containers, based on a 20" container volume of 33.2 m3 (idem) and a specific biomass pellet density of 650 kilograms per cubic meter. With 21580 kilograms of pellet load, each container approximates its maximum pay-load capacity of 21750 kilograms. Each container and pellet load combined weigh approximately 24000 kilograms (Schmied *et al*, 2010). However, it is assumed that the maximum pay-load capacity of PANAMAX vessels relate to the container contents only, i.e. excluding the weight of the container itself. In case transport duration exceeds 22 days - even by one day, an extra ship would be required. In that case, sufficient storage capacity at the harbour should prevent deployment of under-loaded ships. The emission calculations are based on using (nearly) fully loaded vessels as described above.

Two references are used for calculating the pellet shipping emissions. Amoasah (2010) extrapolates emission data by Bradley *et al* (2009), on the basis of total fuel use by a 22000 ton bulk carrier travelling 14000 kilometers. The resulting emission factor of 0.15 MJ per TKM is then used to calculate emissions for a 80.000 ton PANAMAX travelling between Alexandria and Rotterdam.
Estimations by Schmied *et al* (2010) are based on 11.02 grams of CO_2 equivalent per TKM, for vessels carrying 14.5 tons per TEU (20 foot container). The outcome of both methods is presented in *Table 7* and *Table 8* respectively.
The travel distance between the ports of Alexandria and Rotterdam is 5827 kilometers (www.searates.com/reference/portdistance). An important factor is the amount of pay-load that each vessel carries on its way back from Rotterdam to Alexandria. In case the vessels return empty, emissions per ton pellets are assumed to double. Calculations in *Table 7* and *Table 8* are based on an assumed return load of 30 percent.

Table 8: CO_2 emissions according to Bradley (2009: in Amoasah, 2010)

T pellet.year^{-1}	*A-R KM*	*Return load*	*Tonnage.KM*	*MJ.TKM^{-1}*	*Kg CO2.MJ^{-1}*	*Kg CO_2.year^{-1}*
1550957	5827	30%	232017502	0.15	0.074853	**71047661**

Table 9: CO_2 emissions according to Schmied *et al* (2010)

T pellet.year^{-1}	*A-R KM*	*Return load*	*Tonnage.KM*	*Kg CO_2.TKM^{-1}*	*Kg CO_2.year^{-1}*
1550957	5827	30%	232017502	0.01102	**69731806**

The outcome of both methods is very similar. The emission reduction calculations in chapter 2 are based on the method by Bradley *et al* (2010).

2 Net emission savings calculations

2.1 Applied formula

The pellets will be used for co-firing in Dutch electricity plants running on coal. The applied formula for GHG savings (section 1.2) compares grams of carbon dioxide equivalent emitted from the production and usage of a Mega Joule (MJ) of pellets in co-firing (gCO_2- e /MJ_{pellet}), with grams of CO_2- e emitted from the production and use of fossil coal (gCO_2- e /MJ_{coal}).

E_B is obtained by calculating for each emission factor the CO_2 -equivalent emissions per kilogram pellets and divide that by the Lower Heating Value of rice straw pellets, which is assumed to be 14 MJ per kilogram (www.ecn.nl/Phyllis). This value is quite low when compared to a “dry and ash-free” heating value of 18.2 (idem), but may match better the expected high ash contents of rice straw produced on fertile Egyptian soils (possibly 10 to 20%). The result is then divided by 0.4, assuming a coal-to-energy efficiency of 40%.
The fossil fuel comparator E_F is based on emissions of coal-fired power plants and estimated at 200 grams of CO_2 per MJ of coal generated electricity. This figure is based on 133,89 gCO_2 per MJ electricity for the Dutch production mix (Ecofys, 2010).

As *Table 10* shows, the calculation results in net GHG emission savings of 79,97 % as compared to the fossil fuel comparator.

Table 10: emissions and emission reductions as a result of using rice straw pellets for co-firing

CO_2 –equivalent emissions and savings			
Operation	***Factor***	***T CO_2-e/year***	***gCo_2-e/MJ_{pellet} electricity***
Rice straw baling	E_{EC}	18572	2.14
Rice straw supply	E_{TD}-1	29913	3.44
Rice straw pelletizing (including milling and conveyer belt transport to silo)	E_P	104659	12.05
Pellet transport to Alexandria	E_{TD}-2	125109	14.40
Pellet shipment to Rotterdam	E_{TD}-3	71048	8.18
Total CO_2 equivalent bio-chain emissions	$\mathbf{E_B}$	**349301**	**40.22**
Fossil fuel comparator	E_F		200
Net GHG emission savings	$(E_F-E_B)/E_F$		**79,89 %**

2.2 Conclusions

The results suggests that Egyptian rice straw use for co-firing in Dutch electricity plants may indeed meet the requirements for net emission savings set by the RED and NTA 8080 standards. With 79,89 percent of savings, the biomass chain operations stay clear of the minimum emission savings of 70%. This result may hold promise for future biomass based business development in Egypt, and the possibility of certifying biomass operations against international sustainability standards for improved market access.

However, any results should be treated with some caution. Any slight change of one or more important calculation variables may have a big impact on the final result. This is the case, for example, for the emission factor of coal-fired electricity plants. Also, so-called *indirect effects* have not been taken into consideration, that may occur as a consequence of using rice straw for energy purposes. Rice straw prices may increase as a result and this could lead to land use changes, in Egypt and elsewhere. The international debate on iLUC is very much on-going and researchers around the world are seeking ways to quantify these effects. ILUC can potentially undermine sustainability of biomass chains, even if the *direct* effects result overall positive. As long as there is no agreed upon *iLUC factor*, no biomass chain sustainability study should claim to have the final answer. The same holds true for the GHG calculations performed in this study.

Another emission factor worthy of further exploration in the context of Egypt is the *emission savings from carbon capture and replacement* (E_{ccr}). Here too, lack of a reliable methodology is the reason this factor was not included in the study. Current practices in Egypt, of large-scale rice straw burning and rotting on the fields, produce enormous amounts of GHG. Use of rice straw for energy purposes would help avoid these emissions, even more so through substitution of fossil fuels in electricity plants.

It is highly recommendable that more research funding goes into development of methodologies, for more accurate and reliable estimations of biomass related GHG emissions and other effects on sustainability. This is crucial for assessing the real importance of biomass-to-energy operations, as an instrument to reduce global GHG emissions, protect the environment and help alleviate poverty.

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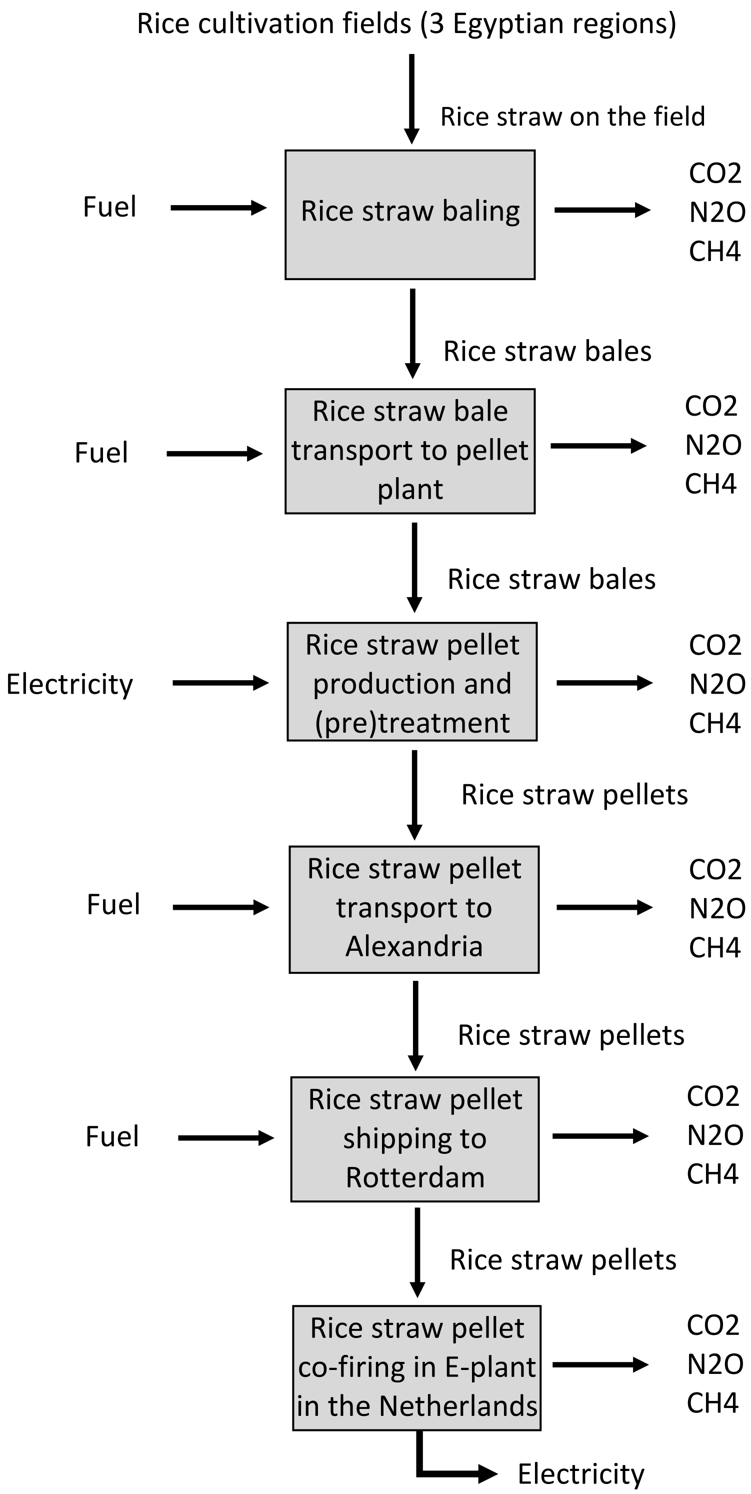
www.searates.com/reference/portdistance (port distance and travel time calculations)

www.ecn.nl/phyllis/ (Lower Heating Value estimations for biomass sources)

Annex 1: Egyptian rice straw-to-energy flow-chart



Annex 2: GHG Emissions Calculation Tool

CO2 equivalent emissions and savings of an Egyptian rice straw-to-energy chain

E_ec (rice straw baling)

	Area (ha)	Tons/ha	Production	Liter/ton	Liter/year	MJ/year	Kg CO2/year	gCO2/kg pellet	gCO2/MJ pellet
Kafr el Sheikh	103870	4	415480	3.77	1566359.6	57250443	4797587	11.97	0.855340393
Dakahlia	174590	4	698360	3.77	2632817.2	96229469	8064029	11.97	0.855340393
Sharkia	123640	4	494560	3.77	1864491.2	68147153	5710731	11.97	0.855340393
Total	402100		1608400	3.77	6063668	221627065	18572348	11.97	**0.855340393**
									2.138350981
									gCO2/MJ pellet E

Basic Input Data

Diesel:	36.55	MJ/liter
	83.8	gCO2-e/MJ
Coal-fired E-plant:	0.40	MJ E/MJ coal
	200.00	gCO2/MJ E
LHV Pellets:	14.00	MJ/kg

E_p (rice straw pelletizing)

	T Straw (12%)	T Pellets (8%)	kwh/ton	kwh /year	kg CO2/kwh	Kg CO2/year	gCO2/kg pellet	gCO2/MJ pellet
Kafr el Sheikh	415480	400641	140	56089800	0.482	27035284	67.48	4.82
Dakahlia	698360	673419	140	94278600	0.482	45442285	67.48	4.82
Sharkia	494560	476897	140	66765600	0.482	32181019	67.48	4.82
Total	1608400	1550957	140	217134000	0.482	104658588	67.48	**4.82**
								12.05
								gCO2/MJ pellet E

E_td 1 (rice straw supply)

	# Pelletizers	Area (ha)	Tons/ha	Production	Radius (km)	Avg. distance	Avg. return	Ton.kilometer	kgCO2/tkm	KgCO2/year	gCO2/kg pellet	gCO2/MJ pellet
Kafr el Sheikh	1	103870	4	415480	18.19	36.38	72.75	30226674	0.221	6680095	16.67	1.1910
Dakahlia	1	174590	4	698360	23.58	47.16	94.32	65869476	0.221	14557154	21.62	1.5441
Sharkia	1	123640	4	494560	19.84	39.69	79.37	39254880	0.221	8675328	18.19	1.2994
Total	3	402100		1608400				135351029		29912577	19.29	**1.3776**
												3.4440
												gCO2/MJ pellet E

GHG savings calculations

Operation	*Emission factor*	*Emissions*
Baling straw	E_ec	2.14
Supply bales	E_td	3.44
Pelletizing	E_p	12.05
Transport to A	E_td	14.40
Shipment to R	E_td	8.18
	E_b	**40.22**
Fossil comparator:	E_f	200.00
Savings:	**(E_f-E_b)/E_f**	**79.89%**

E_td 2 (pellet transport to Alexandria)

	T Pellets (8%)	Return distance	Ton.kilometer	kgCO2/tkm	KgCO2/year	gCO2/kg pellet	gCO2/MJ pellet
Kafr el Sheikh	400641	240	96153943	0.221	21250021	53.04	3.7886
Dakahlia	673419	450	303038357	0.221	66971477	99.45	7.1036
Sharkia	476897	350	166914000	0.221	36887994	77.35	5.5250
Total	1550957		566106300		125109492	80.67	**5.7619**
							14.4046
							gCO2/MJ pellet E

E_td 3 (pellet shipment to Rotterdam)

T Pellets (8%)	working days	Ton per day	Travel days	T.travel days	Ships needed	N ships	T pellet per ship	N containers	Km Rotterdam	Return load	Ton.kilometer	MJ/trip	Kg CO2 per trip	KgCO2 per year	gCO2/kg pellet	gCO2/MJ pellet
1550957	300	5170	22	113737	1.42	2	56868	2635	5827	0.3	232017502	34802625	2605081	71047661	45.81	**3.2721**
													2556833	69731806	44.96	**3.2115**
																8.1802
																gCO2/MJ pellet E

ρ pellets	Volume TEU	Max pay load PANAMAX			Ship oil use	Panamax (like)
650	33.2	80000	5000	21750	0.15	11.02
Kg/m3	M3/TEU	Total tonnage	N containers	T/TEU	MJ/ton.km	gCO2-e/ton.km

Global Warming Potentials (RED,2009)			Emission factors ship transport (IPCC, 2006)		
23	1	296	0.000007	0.0741	0.000002
CH4/CO2	CO2/CO2	N2O/CO2	kgCH4/MJ	kgCO2/MJ	kgN2O/MJ