AGRICULTURAL UNIVERSITY OF ATHENS
DEPARTMENT OF AGRICULTURAL ECONOMICS AND DEVELOPMENT
POSTGRADUATE PROGRAMME IN AGRIBUSINESS MANAGEMENT

DOCTORAL DISSERTATION

ECONOMIC AND ENVIRONMENTAL EVALUATION OF BIOFUEL PRODUCTION PROCESS IN SUGAR INDUSTRY IN THE EUROPEAN UNION

Md. Imdadul Haque

Supervisor: Stelios Rozakis, Associate Professor, AUA

Athens, June 2011

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CONTENTS

Extended Summary

According to recent reforms in the Common Agricultural Policy and the sugar regime, European Commission has encouraged reduction of domestic sugar production in less efficient regions (high production cost or lower sugar beet yield comparing with EU 25 average). At the same time, the European Commission considers transportation bio-fuels as a key factor for reducing reliance on imported fuels and emission levels of greenhouse gases.

Under the new CAP, the Greek sugar quota is reduced by 50 percent, the Hellenic Sugar Industry (HSI) has benefited by the amount of €118 million from the EU. In order for the HSI to accept the reduction of the quota, the EU has offered financial support to the Greek Industry to be spent for restructuring and investment.

According to the Commission's suggestion, the Hellenic Sugar Industry decided to reduce their sugar production by about 160 thousand tons of sugar. Thus the industry has decided to transform 2 sugar plants (out of 5 countrywide) for alternative use like bio-ethanol production using sugar beet and molasses. Technical feasibility and cost analysis of the conversion to ethanol has been undertaken in previous research work (Maki, 2007). Ad hoc economic evaluation based on regional arable agriculture context in Thessaly has suggested beet as the main input coupled by grain so that industrial equipment operates the maximum to optimize its use. Various studies estimating raw material supply has suggested different annual or perennial energy plantations. This research has retained the option of wheat grain to transform to ethanol, cultivated in irrigated land previously exploited producing cotton, maize and other intensively irrigated crops (Rozakis et al., 2001). Wheat cultivation can be highly productive in this region if supplied by one or two spring irrigation rounds thus supplying the ethanol plant minimizing the area cultivated for energy, given that yields of grain may exceed 7 t per ha instead of up to 3 for dry wheat cultivation.

The base capacity of the unit (35000 t EtOH) determines the cost of investment, the cost of equipment, the requirements for the workforce and a line from costs (direct and indirect) that concerned the economic analysis as well as a pattern of the final cost of the first and auxiliary materials, the cost of electrical energy and steam, the cost of maintenance and other costs of operations that concern the production and the administrative support of the unit. Capacity range of the plant is considered from 10000 t to 120000 t ethanol per year. Beside the above elements, an autonomous biogas plant is considered in this study (Configuration 2) to generate electricity and heat for the plant enhancing autonomy of the industrial processing. By-products like pulp and DDGS will be used for biogas production. The main relationships shaping the feasible area of the industry model deal with capacity, sugar-beet to wheat ratio to ensure maximal duration of operation during the year, and capital cost linked to size.

On this track, this study aims to answer the question, whether (and in which configuration) the conversion of sugar factory to an ethanol production plant is economically viable and environmentally favorable, considering the existing facilities (HSI plant at Larissa) and equipment of sugar plant and farming practice of the surrounding area under current agricultural and environmental policy constraints.

In order to accommodate CAP revised in 2003 and Greek sugar industry perspective, mathematical programming is used to evaluate the conversion of the sugar factory to an ethanol production plant. Partial equilibrium agricultural sector modelling and engineering approaches, applied to the industrial model, are jointly exploited to determine the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply. Thus industry aims at maximizing profits whereas the most efficient farmers will provide beet and grain at the lowest possible prices. At the same time environmental impact of bio-fuel production is assessed regarding water consumption and greenhouse gases emissions within a life cycle assessment (LCA) framework. The novelty of the model is that it can accommodate policy parameters and can generate results of different policy scenarios simultaneously in the industry and the agricultural sector.

Farms which cultivated at least one stremma (one tenth of a hectare) of cotton or at least one with sugar beet for the farming period 2001-2002 were selected for the study. A group of 344 arable farms monitored by the Farm Accountant Data Network (FADN), representing in total 22,845 farms of the region is selected as sample. In the present study we use data on farm structure, costs and yields from 2001-2002, i.e., under the CAP known as Agenda 2000 (scenario 1) then changes of CAP in 2003 and 2004, i.e., new CAP basic feature being decoupling of aids and cross compliance that are introduced in the model (scenario 2). A new policy adopted in 2009 in Greek agriculture that coupled subsidy on cotton cultivation at the rate of 80 Euro per ha that was 55 Euro per ha in 2003 new CAP reform is also introduced into the model and its impacts on crop mix, land opportunity cost and consequently in ethanol cost and economics are evaluated. Main constraints are: available land (both total land area and area by land type such as irrigated, non irrigated etc.), irrigation water availability constraints, crop rotational constraints, environmental constraints, and so forth.

The impact of agriculture on the environment is considerable and complex, comprising both positive and negative effects which take place at local, regional, national and global levels. A typical example of a negative effect is the pressure that irrigated agriculture imposes on water quality and quantity. Irrigated agriculture utilizes about 30% of total water consumption at the European scale, while this proportion is considerably higher as far as Southern Europe is concerned, where agriculture consumes about 70-80%. Consequently, water management policy has to take into consideration the extent of water demand from agriculture. Since the ethanol production affects the crop mix in the region likely including wheat to ethanol that even irrigated may replace water greedy crops such as cotton, impacts to water demand due to the transformation of sugar to ethanol plant are considered.

GHG emission in the bioethanol production system is incorporated in the model to examine environmental performance of biofuel production system. Emission of different greenhouse gases is estimated on the basis of kilograms of carbon dioxide equivalent (CO_2e) using life cycle assessment approach. CO_2 emission in biomass production, transportation as well as in the industrial processing is taken into account. CO_2 emission in the agricultural sector is estimated considering direct and indirect land use change due to the introduction of energy crops in the cropping mix. Furthermore since GHG emissions has consequences at the global level, emissions due to imports of food substituting for conventional crops replaced by wheat and beet to ethanol. On the other hand, CO_2 emission from fossil fuel that replaced ethanol is also taken into consideration.

To estimate the cost of CO_2 emissions saving, net saving is calculated. Net CO_2 savings from the agriculture due to change in farming practice after introduction of energy crops, emissions occurred during the industrial process and the amount of saving due to replacement of fossil fuel by bioethanol. Direct cost of CO_2 saving is calculated by the amount of subsidy for biofuel and/or the amount of tax on fossil fuel to be replaced by bioethanol as because biofuel in Greece is exempted from taxes. The deadweight loss that the society has to pay for CO_2 saving is derived if economic surplus captured by the agents involved in the bioethanol chain is deduced by the budgetary burden incurred due to tax credits. Monte Carlo Simulation technique can be accommodated in the agro-industrial model to analyze uncertainty and expected outcome in changing conditions.

The model results shows that, in the agricultural sector, optimal cropping plan for scenario 1 (CAP 2000) approach closely to the observed surfaces cultivated at the regional level by main crops in the base year 2002 forming a validation test proving the selected model specification can be used to perform predictions of the farmers' behavior under different parameters' sets. In the optimal solution when the model runs under the CAP 2003 regime (scenario 2), cotton cultivation is significantly decreased, replaced by maize, alfalfa and soft wheat. Also sugar beet almost disappears due to drastic price reductions within the revised CMO. Introduction of energy crop in the model under new CAP causes significant changes in crop mix and evolution of crop mix with the increase of plant size is appeared prominently. All crop areas except alfalfa are decreased and sugar beet and irrigated wheat is increased with the plant size.

At the industry, average capital cost is decreased with the increase in plant size but variable cost per ton of ethanol production is appeared almost constant in all plant capacities. The feedstock (sugar beet and wheat) cost has a positive slope amounting almost at 50% of total cost for small plants but this element increases to 60% for 120000t (highest capacity) plant. The model maximizes total profit, thus it proposes the highest possible capacity within the predetermined range of 120000 ton ethanol per year. Optimal size is determined by the integrated agro-industrial model under various policy and technical assumptions. Total net cost of ethanol production after deduced income from sale of by product is appeared 735.4 Euro per ton without biogas plant and 837 Euro per ton with biogas plant. This cost is 824.8 and 926.6 Euro per ton under subsidy on cotton at 80 Euro per ha for without and with biogas plant, respectively.

Environmental impact of bioethanol production in the sugar industry has been estimated in terms of net change in CO_2eq emission at the atmosphere. Different scenarios are considered to estimate GHG performance of bioethanol production system. Firstly the absolute CO_2eq emission considering only direct land use change (LUC) for feedstock production, emission for transportation and for industrial transformation. In the second scenario, GHG emission for indirect land use change (iLUC) is considered. GHG differentials for without and with the cultivation of energy crop is evaluated within the regional boundary of Thessaly. In the third scenario, along with iLUC in regional boundary of Thessaly, global GHG potential is considered.

Total net CO_2 saving at optimal solution in different plant size is appeared increasing but CO_2 emission savings per ton ethanol is decreasing with the plant size increase in the first scenario. Under the second scenario, GHG performance is improved substantially, both total net CO_2 saving and CO_2 savings per ton ethanol is appeared in decreasing trend. Results in third scenario appeared more or less similar to the second scenario but CO_2 saving per ton ethanol is unstable with plant size. Total net CO_2 saving at the optimal plant size of 120kt in first, second and third scenario is 70.6, 171.9 and 172.6kt and emission saving per ton is 0.588, 1.432 and 1.438 ton, respectively. Under the new policy of subsidy on cotton cultivation at the rate of 80 Euro per ton, total net CO_2 emission saving in above mentioned three scenarios is 71.1, 159.1 and 198.4kt and emission saving per ton ethanol is 0.593, 1.326 and 1.653 ton, respectively.

Cost of CO_2 saving per ton of ethanol production under the first scenario is appeared high and increasing with increase of plant size. On the other hand under the second and third scenarios, cost of CO_2 saving is decreasing with plant size increase. At the optimal plant size of 120kt ethanol plant, cost of CO_2 saving under first, second and third scenarios is 738.2, 303.2 and 301.9 Euro per ton CO_2eq, respectively. Under the policy of subsidy on cotton cultivation at 80 Euro per ha, cost of CO_2 saving at the first, second and third scenarios is appeared 883.2, 394.8 and 316.7 Euro per ton CO_2eq, respectively.

It is evident that in absolute terms, on an average 24% CO_2 emission for bioethanol production is caused by feedstock production and 75% emission is occurred in industrial processing whereas only 1% is caused transportation. With the optimal plant size of 120kt ethanol per year, 302.6kt CO_2 emission caused by gasoline can be avoided by replacing with ethanol. Thus, significant amount of CO_2 emission can be avoided both in agricultural sector by the introduction of energy crop in crop mix the replacement of gasoline with bioethanol but cost of CO_2 saving is appeared to be expensive.

It is observed in the study that, restricting of the Larissa sugar factory to an ethanol production plant potentially economically advantageous to the Greek producers as because the farmer can gain satisfactory returns from their farm production and can avoid the support cut on sugar beet production at the same time the Greek sugar producer can survive through restructuring the industry and can accommodate with the EU's CMO for sugar compulsory quota cuts. The restructuring will help to achieve biofuel quota attaining 5-10% of the gasoline consumption and environmental policy target provided by the European Commission also. In general, the restructuring will help to improve macroeconomic parameter like income and unemployment of the country as a whole.

Several studies have been done on economic evaluation of ethanol production in sugar industry (Soldatos and Kallivroussis, 2001; Anonymous, 2006; Maki, 2007). Previous studies were mainly concentrated on profitability of ethanol production and competitiveness compare to petroleum fuel from the viewpoint of the industry. Some study (Soldatos et al., 2006) has analyzed economic potentiality of energy crop cultivation. In reality, industrial performance depends on feedstock supply from agricultural production and vice versa.

The present study has made the bridge and exploited optimization in industry and agricultural feedstock supply sector simultaneously. Simultaneous optimization is attained on the basis of the dual product prices and the marginal rate of technical substitution (MRTS). The possible techniques of production activities available to a sector i.e., activity analysis (AA) and the life cycle assessment which aims to quantify the environmental impacts of a product from 'cradle' to 'grave', is integrated that builds life cycle activity analysis (LCAA) methodology (Clift et al., 2000). Along with technical and economic analysis, LCAA for environmental performance analysis has made the study a unique work.

This thesis is organized in 9 chapters excluding this extended summary. In chapter I, an overview on sugar is presented including historic overview, world contemporary sugar situation including sugar trade and policies and a detailed cost and returns analysis of sugarcane and sugar in Bangladesh. Chapter II describes EU reform of sugar CMO and its impacts on sugar production in Europe and world trade and sugar perspective in Greece. An overview of biofuel and bioethanol is presented in chapter III followed by GHG emission in biofuel production system including detailed life cycle GHG emission calculation in different stages of bioethanol production process is described in chapter IV. Methodology for economic evaluation of bioethanol production potentiality in Larissa sugar plant including detailed mathematical programming model for agricultural and industry sector as well as their integration technique is detailed in chapter V. In chapter VI, case study of ethanol plant in

Thessaly is described. Uncertainty and risk analysis using Monte Carlo simulation method is presented in chapter VII. Model optimization results and discussion is presented in chapter VIII and concluding remarks is presented in chapter IX.

Εκτενής Περίληψη

Οικονομική και περιβαλλοντική αξιολόγηση της διαδικασίας παραγγής βιοκαυσίμου από τη βιομηχανία ζάχαρης στην Ευρωπαϊκή Ενωση

Ως αποτέλεσμα της μεταρρύθμισης της Κοινής Αγροτικής Πολιτικής (ΚΑΠ) η Ευρωπαϊκή Ενωση ενθάρρυνε τη μείωση της παραγόμενης ποσότητας ζάχαρης στις λιγότερο ανταγωνιστικές χώρες μέλη. Την ίδια εποχή προωθήθηκε η παραγωγή βιοκαυσίμων για την αντιμετώπιση της εξάρτησης από τα ορυκτά καύσιμα και τη μείωση των εκπομπών αερίων θερμοκηπίου. Με το νέο καθεστώς η ποσόστωση για την Ελλάδα μειώθηκε στο 50%, ενώ η Ελληνική Βιομηχανία Ζάχαρης αποζημιώθηκε με το ποσό των €118 εκατομμυρίων το οποίο είχε προβλεφθεί για να ενισχύσει την αναδιάρθρωση του τομέα. Πιο συγκεκριμένα η Ελληνική πλευρά επέλεξε να μειώσει την παραγωγή κατά 160 χιλ. τόνους με τη μετατροπή δύο εκ των πέντε συνολικά εργοστασίων παραγωγής ζάχαρης σε μονάδες παραγωγής αιθανόλης.

Αρκετές μελέτες έχουν γίνει για την οικονομική αξιολόγηση της παραγωγής αιθανόλης από την βιομηχανία ζάχαρης (Soldatos and Kallivroussis, 2001; Anonymous, 2006; Research, 2006; Maki, 2007). Επικεντρώθηκαν κυρίως στην κερδοφορία της παραγωγής αιθανόλης και στην ανταγωνιστικότητα της σε σχέση με το πετρέλαιο από την οπτική γωνία της βιομηχανίας. Κάποιες μελέτες (Soldatos et al., 2006) έχουν αναλύσει τις οικονομικές δυνατότητες των ενεργειακών καλλιεργειών. Οι εργασίες αυτές επικέντρωσαν στην περιοχή της Θεσσαλίας, μελέτησαν το κόστος μετατροπής αξιοποιώντας υπάρχοντα εξοπλισμό και επίσης διερεύνησαν τις δυνατότητες προμήθειας πρώτης ύλης για παραγωγή αιθανόλης. Εκτιμήθηκε ότι για άριστη αξιοποίηση του εξοπλισμού πρέπει να επιδιωχθεί να λειτουργεί η μονάδα καθόλη τη διάρκεια του χρόνου συμπληρώνοντας τη σακχαρώδη με κάποια αμυλώδη πρώτη ύλη η οποία μπορεί να αποθηκευθεί και να τροφοδοτεί το εργοστάσιο επιτυγχάνοντας βέλτιστη διαστασιοποίηση. Από διάφορες επιλογές θεωρήθηκε εφικτή η λύση του σιταριού αφενός λόγω της εμπειρίας από την Ευρώπη, αφετέρου διότι η περιοχή διαθέτει εκτάσεις κυρίως καλλιεργούμενες με βαμβάκι που θα μπορούσαν να διασφαλίζουν την ομαλή τροφοδοσία της μονάδας.

Η παραγωγή σιταριού μπορεί να γίνει πολύ αποδοτική στην περιοχή, ειδικά αν το φυτό αρδευθεί το Μάϊο φτάνοντας τους 7-8 τόνους το εκτάριο, με αποτέλεσμα την απαίτηση περιορισμένων εκτάσεων για την τροφοδοσία του εργοστασίου παραγωγής βιο-αιθανόλης.

Η δυναμικότητα της μονάδας προσδιορίζει το κόστος επένδυσης καθώς και τα λειτουργικά κόστη. Με βάση προσφορές από κατασκευαστικές εταιρείες αλλά και τη διεθνή εμπειρία εκτιμήθηκαν τα κόστη για μεγέθη από 10 έως 120 χιλιάδες τόνους αιθανόλης, μετασχηματίζοντας τα στοιχεία σε συνεχείς συναρτήσεις με ανεξάρτητη μεταβλητή το κόστος. Επιπρόσθετα εκτιμήθηκε το κόστος παραγωγής βιοαερίου μέσα στη μονάδα που παράγει ηλεκτρική και θερμική ενέργεια για τις ανάγκες της μονάδας χρησιμοποιώντας τα υποπροϊόντα της διαδικασίας παραγωγής. Εξετάστηκαν δηλαδή δύο τεχνικές παραγωγής αιθανόλης (με και χωρίς υπομονάδα βιοαερίου) και έγινε σύγκριση σε σχέση με τις οικονομικές και περιβαλλοντικές τους επιδόσεις.

Η παρούσα μελέτη έχει προσπάθησε να γεφυρώσει το χάσμα μεταξύ υποδειγμάτων του γεωργικού τομέα και της βιομηχανικής μετατροπής στοχεύοντας στη μεγιστοποίηση του συνολικού πλεονάσματος. Η διατριβή αυτή επιχείρησε να απαντήσει το ερώτημα αν η μετατροπή σε μονάδα παραγωγής βιοαιθανόλης είναι οικονομικά βιώσιμη και περιβαλλοντικά ενδιαφέρουσα, μελετώντας την υφιστάμενη κατάσταση τόσο στο βιομηχανικό στάδιο όσο και στο γεωργικό τομέα.

Για να ληφθούν υπόψη τα οικονομικά δεδομένα, το καθεστώς πολιτικής και η προοπτική της ζάχαρης και των βιοκαυσίμων, χρησιμοποιήθηκε ο μαθηματικός προγραμματισμός για οικονομική αξιολόγηση. Ενα τομεακό υπόδειγμα μερικής ισορροπίας και βιομηχανικά υποδείγματα βελτιστοποίησης συνδέθηκαν σε ενιαία μορφή για να προσδιοριστεί η καλύτερη τεχνική και η βέλτιστη δυναμικότητα της μονάδας παραγωγής βιοαιθανόλης, καθώς επίσης και το είδος και οι ποσότητες πρώτης ύλης. Η βιομηχανία επιδιώκει τη μεγιστοποίηση του κέρδους και την παραγωγή με το ελάχιστο κόστος, δηλαδή τη βέλτιστη οργάνωση της παραγωγής και την προμήθεια πρώτης ύλης στην χαμηλότερη δυνατή τιμή. Οι γεωργοί επιδιώκουν να μεγιστοποιήσουν το βραχυπρόθεσμο όφελος δηλαδή το ακαθάριστο κέρδος της εκμετάλλευσης υπό περιορισμούς (τεχνικούς, οικονομικούς, πολιτικούς κλπ).

Η χρηματο-οικονομική βέβαια βιωσιμότητα των βιοκαυσίμων βασίζεται σε φοροαπαλλαγές διότι το κόστος τους είναι σημαντικά υψηλότερο από εκείνο των ανταγωνιστικών προϊόντων ορυκτών καυσίμων. Για το λόγο αυτό εξετάζεται το περιβαλλοντικό αποτέλεσμα της δραστηριότητας. Δύο διαστάσεις της επίπτωσης της παραγωγής βιο-αιθανόλης στη Θεσσαλία λαμβάνονται υπόψη και συγκεκριμένα η ποσότητα νερού που καταναλώνεται για άρδευση καθώς και οι εκπομπές αερίων θερμοκηπίου που εκλύονται. Μεγαλύτερη έμφαση έχει δωθεί στο προσδιορισμό της ποσότητας αερίων θερμοκηπίου σε ισοδύναμο διοξείδιο του άνθρακα με χρήση της μεθοδολογίας Ανάλυσης Κύκλου Ζωής. Μία καινοτομία της διατριβής είναι ότι έχει δημιουργήσει το πλαίσιο (υπόδειγμα) με βάση το οποίο μπορεί να υπολογιστεί η επίδραση διαφορετικών σεναρίων πολιτικής (πχ. Αγροτικής Πολιτικής) μέσω της μεγιστοποίησης του συνολικού οικονομικού αποτελέσματος (βιομηχανίας και γεωργικού τομέα) στις καθαρές εκπομπές που προκύπτουν από την παραγωγή βιοαιθανόλης.

Ενας αριθμός 344 εκμεταλλεύσεων που καλλιεργούν ζαχαρότευτλα ή/και βαμβάκι για τις οποίες διαθέτουμε στοιχεία από το Ευρωπαϊκό Γεωργικό Λογιστικό σύστημα σχηματίζουν το υπόδειγμα του γεωργικού τομέα και είναι θεωρητικά υποψήφιες να παράξουν ενεργειακή βιομάζα. Οι εκμεταλλεύσεις αυτές είναι αντιπροσωπευτικές και τα αποτελέσματα προβάλλονται με βάση στάθμιση που έχει υπολογιστεί από το στατιστικό σύστημα. Μέσα από το υπόδειγμα μαθηματικού προγραμματισμού μεγιστοποιείται το ακαθάριστο κέρδος υπό περιορισμούς (διασθεσιμότητας πόρων, αγρονομικών κανόνων, αγορές, ποσοστώσεις, πολλαπλή συμμόρφωση κλπ) εκτιμώνται οι αμειψισπορές, το κόστος ευκαιρίας της γής και τα οικονομικά αποτελέσματα (ακαθάριστο κέρδος, γεωργικό εισόδημα κλπ) για διαφορετικά σενάρια πολιτικής τόσο για την ΚΑΠ του 2000 όσο και για το καθεστώς αποδέσμευσης (ΚΑΠ 2003) με τις μεταγενέστερες διατάξεις (ΚΟΑ ζάχαρης και βαμβακιού).

Το αποτέλεσμα των εκπομπών αερίων θερμοκηπίου που προκύπτει από τις δραστηριότητες που σχετίζονται με την παραγωγή αιθανόλης (καλλιέργεια, συγκομιδή, μεταφορά, μετατροπή) ενσωματώνεται στο υπόδειγμα συμπεριλαμβάνοντας τις άμεσες αλλά και τις έμμεσες εκπομπές καθώς και αυτές που απορρέουν από την εξοικονόμηση πόρων πχ. την μείωση εκπομπών λόγω υποκατάστασης βενζίνης από αιθανόλη. Υπολογίζεται τελικά η καθαρή εξοικονόμηση καθώς και το συνολικό οικονομικό κόστος για την κοινωνία που απαιτείται για αυτό. Για να υπολογιστεί το οικονομικό κόστος (deadweight loss) αφαιρελιται από τη συνολική επιβάρυνση των φορολογούμενων (διαφυγή εσόδων στο προϋπολογισμό από το φόρο στα πετρελαιοειδή λόγω φοροαπαλλαγής των βιοκαυσίμων) το πλεόνασμα των παραγωγών (βιομηχανία και γεωργία). Το ενιαίο υπόδειγμα είναι σε θέση να υπολογίσει το συνολικό αλλά και τα επιμέρους πλεονάσματα για οποιαδήποτε τιμή αιθανόλης, μέγεθος εργοστασίου και τεχνολογίας μετατροπής καθώς και την κατανομή του γεωργικού πλεονάσματος παραγωγού ανάμεσα στους παραγωγούς σιτηρών και ζαχαροτεύτλων. Ετσι μπορεί να προσδιοριστεί ο άριστος συνδυασμός για την οικονομία, τους φορολογούμενους, το περιβάλλον και τους επιμέρους παράγοντες της αλυσίδας.

Το μέσο κόστος κυμαίνεται μεταξύ 800 και 1000 ευρώ ανά τόνο αιθανόλης και συνίσταται σε περίπου 70%-30% σχέση κόστους πρώτης ύλης προς κόστος μετατροπής. Με δεδομένο αυτο το λόγο επιμέρους αλλαγές στην αγροτική πολιτική έχουν σημαντική επίπτωση στο κόστος της αιθανόλης. Για παράδειγμα η αύξηση της δεσμευμένης ενίσχυσης στο βαμβάκι που εφαρμόστηκε το 2009 καθιστώντας το πιο ανταγωνιστικό και κατά συνέπεια αυξάνει το κόστος ευκαιρίας της γης για τις ενεργειακές καλλιέργειες, έχει αποτέλεσμα την αύξηση του κόστους αιθανόλης κατά περίπου 50 ευρώ τον τόνο και μετατοπίζει το σημείο ελάχιστου κόστους από τη δυναμικότητα εργοστασίου 50 χιλ τόνων σε 25 χιλ τόνους. Η πρόσθεση μονάδας βιοαερίου συμβάλλει στην αξιοποίηση των υποπροϊόντων και την επάρκεια σε ενέργεια. Με δεδομένη όμως την αισιόδοξη τιμή πώλησης της πίτας για ζωοτροφές (που δεν είναι διαθέσιμη στην περίπτωση διοχέτευσης των υποπροϊόντων για βιοαέριο) το συνολικό οικονομικό αποτέλεσμα είναι μειωμένο κατά περίπου 100 ευρώ τον τόνο αιθανόλης.

Το περιβαλλοντικό όφελος από τη μείωση των εκπομπών διοξειδίου διαφοροποιείται ανάλογα με το εύρος των ορίων του συστήματος στο οποίο βασίζεται η ανάλυση κύκλου ζωής. Οταν ληφθούν υπόψη οι έμμεσες αλλαγές χρήσεων γης τα περιβαλλοντικά αποτελέσματα βελτιώνονται και μειώνεται το κόστος ανα μονάδα μείωσης εκπομπών. Αυτό κυμαινεται από 100 έως 250 ευρώ και διαφοροποιείται ανάλογα με τα τεχνικά χαρακτηριστικά και τη δυναμικότητα του εργοστασίου μετατροπής.

Με δεδομένες τις τρέχουσες τιμές της βενζίνης στον καταναλωτή φαίνεται οικονομικά βιώσιμη η παραγωγή αιθανόλης στην Ελλάδα από τις εγκαταστάσεις της βιομηχανίας ζάχαρης. Δεν έχει συνυπολογιστεί το ποσό της ενίσχυσης που δόθηκε με βάση την μεταρρύθμιση στη ζάχαρη διότι έχουν ήδη περάσει 5 έτη εφαρμογής της νέας ΚΟΑ και δεν έχει αναληφθεί η επένδυση στη βιοαιθανόλη (για λόγους που δεν μπορούμε να εξηγήσουμε εδώ). Το συνολικό κέρδος της βιομηχανίας μεγιστοποιείται στη μέγιστη δυναμικότητα (120 χιλ. τόνους), το βέλτιστο σημείο μπορεί να αλλάξει αν μειωθεί η τιμή της βενζίνης στον καταναλωτή ή το ποσό της φοροαπαλλαγής ανά τόνο ή το συνολικό διαθέσιμο κονδύλι από τον προϋπολογισμό για τη στήριξη της βιοαιθανόλης. Η μετατροπή δύο εργοστασίων ζάχαρης επιτρέπει την επίτευξη του στόχου 5-10% που έχει τεθεί από την Ευρωπαϊκή Ενωση.

CHAPTER I: SUGAR OVERVIEW

1.1 Historic Overview: The Origin

Sugar is a sweet crystallized material that consists wholly or essentially of sucrose, is colourless or white when pure tending to brown when less refined, is obtained commercially from sugarcane or beet and less extensively from sorghum, maples, and palms, and is important as a source of dietary carbohydrate and as a sweetener and preservative of other foods [Merriam-Webster's Online Dictionary, (Dictionary)].

Originally, people chewed the cane raw to extract its sweetness. Indians discovered how to crystallize sugar during the Gupta dynasty, around AD 350 (Adas, 2001). Sugarcane was originally from tropical South Asia and Southeast Asia. Different species likely originated in different locations with *S. barberi* originating in India and *S. edule* and *S. officinarum* coming from New Guinea (Sharp, 1998).

During the Muslim Agricultural Revolution from the 8th century to the 13th century, Arab entrepreneurs adopted sugar production techniques from India and then refined and transformed them into a large-scale industry (Watson, 1974). Arabs set up the first large scale sugar mills, refineries, factories and plantations. The Arabs and Berbers spread the cultivation of sugar throughout the Arab Empire and across much of the Old World (Europe, Asia and Africa with surrounding islands), including Western Europe after they conquered the Iberian Peninsula in the eighth century (Hassan, 2005).

The Portuguese took sugar to Brazil. By 1540, Santa Catarina Island had 800 sugar mills and that the north coast of Brazil, Demarara and Surinam had another 2,000. Sugar mills had been constructed in Cuba and Jamaica by the 1520s (Antonio, 1996). Approximately 3,000 small mills built before 1550 in the New World (Americas, Australia) created an unprecedented demand for cast iron gears, levers, axles and other implements. Specialist trades in mold-making and iron-casting developed in Europe due to the expansion of sugar production. Sugar mill construction developed technological skills needed for a nascent industrial revolution in the early 17th century (Antonio, 1996).

After 1625, the Dutch carried sugarcane from South America to the Caribbean islands, where it became grown from Barbados to the Virgin Islands. The years 1625 to 1750 raw sugar become worth its weight in gold. Contemporaries often compared the worth of sugar with valuable commodities including musk, pearls, and spices. Prices declined slowly as production became multi-sourced, especially through British colonial policy. With the European colonization of the Americas, the Caribbean became the world's largest source of sugar. These islands could supply sugarcane using slave labor and produce sugar at prices vastly lower than those of cane sugar imported from the East (Mathieson, 1926). Thus the economies of entire islands such as Guadaloupe and Barbados became based on sugar production. By 1750 the French colony known as Saint-Domingue (subsequently the independent country of Haiti) became the largest sugar producer in the world. Jamaica too became a major producer in the 18th century.

During the eighteenth century, sugar became enormously popular and the sugar market went through a series of booms. The heightened demand and production of sugar came about to a large extent due to a great change in the eating habits of many Europeans. The Europeans began consuming jams, candy, tea, coffee, cocoa, processed foods, and other sweet victuals in much greater numbers. During 1750 sugar surpassed grain as “the most valuable commodity” in European trade. It made up a fifth of all European imports. Reacting to this increasing craze, the islands took advantage of the situation and set about producing more sugar (Ponting, 2000). As Europeans established sugar plantations on the larger Caribbean islands, prices fell, especially in Britain. By the eighteenth century all levels of society had become common consumers of the former luxury product. At first most sugar in Britain went into tea, but later confectionery and chocolates became extremely popular.

During the 18th century, Europeans began experimenting with sugar production from other crops. Andreas Marggraf (German chemist, physicist and biologist) identified sucrose in beet root and his student Franz Achard built a sugar beet processing factory at Cunern in Silesia (in present-day Konary in Poland). However the beet-sugar industry really took off during the Napoleonic Wars (1802 - 1815). Napoleon, cut off from Caribbean imports by a British blockade, and at any rate not wanting to fund British merchants, banned imports of sugar in 1813. The beet-sugar industry then emerged in consequence. Today 30% of the world's sugar is produced from beets (Ponting, 2000).

Beginning in the late 18th century, the production of sugar became increasingly mechanized. The steam engine first powered a sugar mill in Jamaica in 1768, and soon after, steam replaced direct firing as the source of process heat. In 1813 the British chemist Edward Charles Howard invented a method of refining sugar that involved boiling the cane juice in a closed vessel heated by steam and held under partial vacuum rather than in an open kettle. At reduced pressure, water boils at a lower temperature, and this development both saved fuel and reduced the amount of sugar lost through caramelization. Further gains in fuel-efficiency came from the multiple-effect evaporator (Figure 1.1). This system consisted of a series of vacuum pans, each held at a lower pressure than the previous one. The vapors from each pan served to heat the next, with minimal heat wasted. Modern industries use multiple-effect evaporators for evaporating water (Figure 1.2). The process of separating sugar from molasses also received mechanical attention: David Weston first applied the centrifuge to this task in Hawaii in 1852 (Higa et al., 2009).

1.2 Sugar Contemporary Situation

Sugar is a widely marketed commodity all over the world. World sugar production for the 2009-10 marketing year was 153.5 million tons and domestic consumption was 154.9 million tons. Production for the 2010-11 marketing year is forecasted at 161.9 million tons and consumption is forecasted at 158.9 million tons (Table 1.1). On average, international sugar trade amounts to roughly 50 million tons (both raw and refined sugar), or 30 percent of world production (wheat 19%, rice 7%, cotton 27%) (USDA, 2008; Agriculture), 2009; USDA, 2009, 2011). World market price for sugar is highly variable. The price moves erratically and reaches exceptionally high or low levels. Price for the year 2009-10 was 18.7 cents/lb for raw sugar and 22.1 cents/lb for refined sugar.

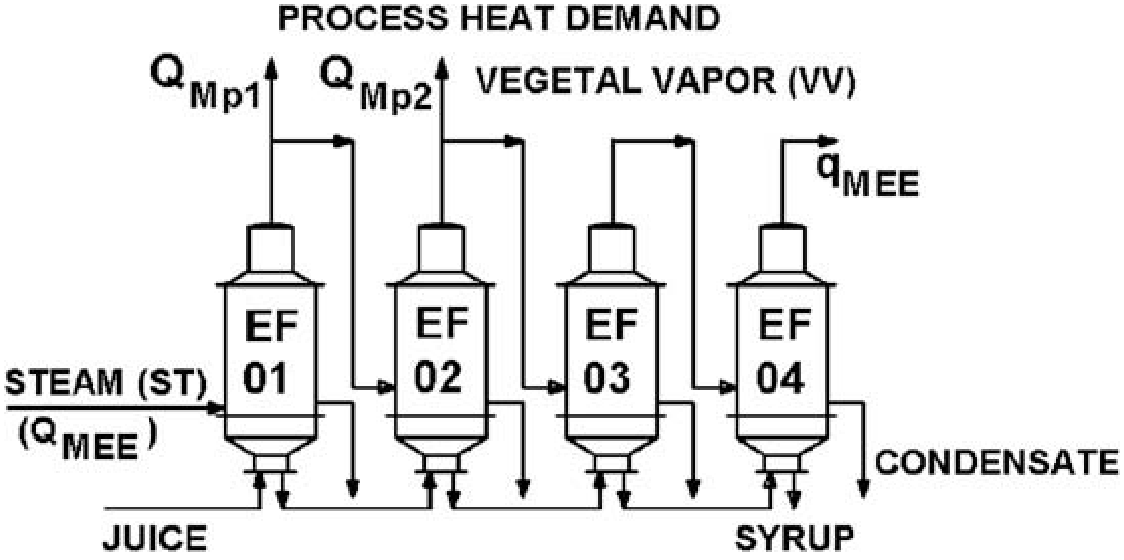

Figure 1.1. Typical configuration of multiple effect evaporator

Source: Thermal integration of multiple effect evaporator in sugar plant (Higa et al., 2009).

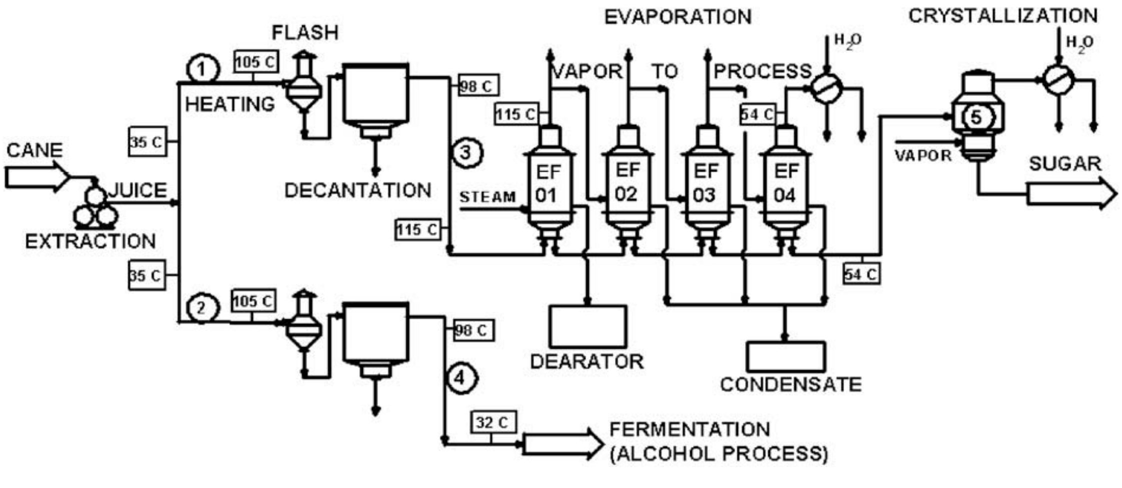

Figure 1.2. Sugar production process.

Source: Thermal integration of multiple effect evaporator in sugar plant (Higa et al., 2009).

Table 1.1 World sugar production, consumption, export, import and price in current decade.

Year	Production (Mt)	Export (Mt)	Import (Mt)	Consumption (Mt)	Price (cents/lb)	
					Raw sugar	Refined sugar
2000-01	130.6	37.7	38.7	129.9	8.5	10
2001-02	134.6	40.9	38.0	134.5	9.1	11.3
2002-03	148.8	46.1	39.9	138.0	7.9	10.4
2003-04	142.0	45.3	39.1	140.2	7.5	9.7
2004-05	141.5	45.5	39.8	140.9	8.6	10.9
2005-06	144.9	49.7	46.1	143.0	11.4	13.2
2006-07	164.2	50.4	46.0	150.8	15.5	19
2007-08	165.4	50.2	45.9	156.1	11.6	14
2008-09	143.9	48.9	47.3	153.7	13.8	16
2009-10	153.5	51.8	51.4	154.9	18.7	22.1
2010-11 (forecast)	161.9	51.8	49.2	158.9		27.8

Source: Sugar and Sweeteners: Data Tables, Foreign Agricultural Service (FAS), Production, Supply and Distribution (PSD) database, Economic Research Service (ERS), USDA.

Brazil is the largest sugar producing country of the world followed by India, Eu-25, China, USA (Table 1.2). Brazil produces about 20 percent of total world production. The world total sugar produces from two main sources: sugarcane and sugar beets. Cane sugar constitutes about 70 percent of world production and 30 percent for beet sugar (Elbehri et al., 2008). Brazil, India, China, Thailand, Mexico, Australia and Pakistan produce sugar mostly from sugarcane, EU-25 and Russian Federation mostly from sugar beet, and the USA produces both from sugarcane and sugar beet (ISO, 2009).

Table 1.2 Ten largest sugar producers (Mt)

Country	**Total**	**Cane sugar**	**Beet sugar**
Brazil	32.29	32.29	-
India	25.94	25.94	-
EU-27	16.38	0.26	16.12
China	15.4	14.43	0.98
Thailand	7.77	7.77	-
USA	6.96	3.08	3.88
Mexico	5.94	5.94	-
Pakistan	5.0	4.99	0.01
Australia	4.62	4.62	-
Russian Federation	3.79	-	3.79

Source: Sugar Year Book 2009, International Sugar Organization, London.

In terms of sugar exporting, Brazil is also at the highest position followed by Australia, Eu-25, Thailand, Guatemala, India (Table1.3). Brazil exports about 40 percent of total world export. Among 10 largest sugar-exporting countries, Brazil, Australia, Thailand, Guatemala, South Africa, Colombia and Argentina export both raw and white (refined) sugar. The EU-25 and India export only white sugar (ISO, 2009). The leading sugar-producing countries are also the leading consumers. Sugar is a widely traded commodity. Among the main features of world sugar trade are (1) the differentiation between raw and refined (white) sugar, (2) the regional character of trade flows, and (3) the existence of policies and subsidies that affect a significant portion of the sugar trade.

Table 1.3 Ten largest net sugar exporters (Mt)

Country	Total	Raw sugar	White sugar
Brazil	20.14	14.10	6.04
Thailand	5.11	2.77	2.34
India	4.23	2.29	1.94
Australia	3.29	3.11	0.18
Guatemala	1.33	0.75	0.59
Mexico	0.95	0.58	0.37
Cuba	0.75	0.75	-
Swaziland	0.61	0.38	0.23
Mauritius	0.4	0.4	-
Argentina	0.38	-	-

Source: Sugar Year Book 2009, International Sugar Organization.

1.2.1 Raw and Refined Sugar

Raw sugar refers to the cane sugar which has been minimally processed. It is the product of the first stage of the cane sugar refining process. Raw beet sugar is not useable as such since the impurities give it a disagreeable taste. The industrial processing of beet is always continued to the white sugar stage of the marketed product. Raw cane sugar, on the other hand, can be ingested as it is. The impurities give it a particular taste, some nutritional value and a natural product image that is of weight with some consumers. A ton of 'standard' raw sugar gives 0.92 tons of white sugar. But the raw cane sugar imported into the European Community gives a yield close to 0.97 ton (EC, 2004).

World trade in cane sugar is primarily at the raw sugar stage but at the consumption stage mostly used refined sugar. Sugar from beet must have to be refined because raw beet sugar is not usable and the average cost of producing sugar from beet is nearly twice the average cost of producing sugar from sugarcane, the raw and refined sugar largely affects the sugar trade.

1.2.2 Regional Character of Trade Flows

Regional trade character is an important factor that influences sugar trade largely. For instance, the US must grant duty-free access to Mexican sugar by 2008 under the North American Free Trade Agreement (NAFTA). Access to the US market for Dominican Republic and Central American sugar is also bound to increase owing to the commitments under the Central America Free Trade Agreement. EU imports of sugar originating from least developed countries (LDCs) will enter duty-free and quota-free in 2009 under the ‘everything but arms’ (EBA) initiative (Gohin and Bureau, 2006).

1.2.3 Existence of Policies and Subsidies

Government policy substantially affects sugar trade. Sugar sector in most of developed country especially in the US, Japan and the EU is heavily subsidized and protected by high tariff (Gohin and Bureau, 2006). The European Union’s sugar policy uses production quotas, import controls, and export refunds (subsidies) to support producer prices at levels which are well above international prices. In Japan, the government intervenes in the sugar market by establishing guaranteed minimum prices for sugar beets and cane, controls on raw sugar imports, prohibitive duties on refined sugar imports, high tariffs on imported products containing sugar, and quotas, tariffs and other controls on sugar substitutes. Sugar beet and sugarcane producer get 10 times world market price. The U.S. sugar policy is to maintain high prices to encouraged rapid production increases. Some other countries have policies which are similar to those of the E.U. (Thailand) or the U.S. (China) and domestic market liberalization in these countries would lead to substantial changes in production, consumption, and trade, with important implications for the world sugar market (Mitchell, 2004).

1.3 Sugar in Bangladesh

Sugarcane and sugar production cost and return is presented in this section in order to compare sugar production competitiveness between Bangladesh as a LDC and the European Union. Detailed cost of production of sugarcane including transportation and process cost in the industry is analyzed.

1.3.1 Location and Topography

Bangladesh is a country in South Asia with a total area of 147570 square kilometer. Bangladesh is located in the tropics between 20°34' and 26°38' North latitudes and 88°01' and 92°41' East longitudes. Three sides of Bangladesh like the north, the east and the west are bounded by India with a small stripe with Myanmar on the southeastern edge. In the south, the country has a long coast along the Bay of Bengal. Topographically the country is almost entirely plain land, only the northeast and southeast small part of the country is hilly area (BBS, 2005).

1.3.2 Climate

Bangladesh has a subtropical monsoon climate with main three seasons- a hot, humid summer from March to May, rainy monsoon season from June to September, and a cool, dry winter from December to February. Spring and autumn (October – November) are brief but can be distinguished in changes in vegetation as well as daily temperature. In general, maximum summer temperature ranges between 32°C and 38°C. April is the warmest month in most parts of the country. January is the coldest month, when the average temperature for most of the country is ranges from minimum of 7°C – 13°C and maximum of 24 - 31°C. Regional climatic differences in this country are minor. Average annual temperature is 26°C. Monsoon starts in July and stays up to October. This period accounts for 80% of the total rainfall. The average annual rainfall varies from 1429 to 4338 millimetre (BBS, 2006).

1.3.3 Agriculture

Bangladesh is primarily an agrarian economy. Although the share of agriculture to GDP has been decreasing over the last few years, yet it is the single largest producing sector of and it contributes about 22% to the total Gross Domestic Product (GDP) of the country. This sector also accommodates around 48.1% of labour force. GDP growth rate of Bangladesh mainly depends on the performance of the Agriculture sector. The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security.

Agricultural holdings in Bangladesh are generally small. However, the use of modern machinery is gradually gaining popularity with cooperative farming. Rice, Jute, Sugarcane, Potato, Pulses, Wheat, Tea and Tobacco are the principal crops. The crop sub-sector dominates the agriculture sector contributing about 72% of total production. Fisheries, livestock and forestry sub-sectors are 10.33%, 10.11% and 7.33% respectively (BBS, 2007).

1.3.4 Demand and Supply of Sugar and *Jaggery*[1] in Bangladesh

Bangladesh is a country with more than 140 million people and it is increasing per year. According to FAO recommendation a minimum of 13 kg per capita sugar consumption per year is required for balanced human diet and calorie requirement. With the increase of population, sugar demand is increasing but the production of sugar and *jaggery* (locally called *Gur*) did not increased as expected even decreased sometimes. Import of sugar increased day by day but the total supply does not satisfy the demand. On an average 35% demand for sugar and *jaggery* are satisfied by home production, 20% by import and 45% remained deficit (Table 1.4).

1.3.5 Sugarcane and Sugar Industry in Bangladesh

Sugarcane is one of the important food-cum-industrial crop of Bangladesh. It plays an important role in providing food, nutrition, employment and foreign exchange savings. It provides employment of 60 million man-days of active force throughout the year. It is drought and flood resistant field crop. Sugarcane is contributing 0.74% in national GDP and 5.52% in agricultural GDP occupying only 2.05% of cultivable land. Out of 30 agro-ecological zones in Bangladesh, sugarcane is grown in 12 zones (BSRI, 2003). At present, 7.3 million tons of sugarcane is produced annually from 0.18 million hectors of land from

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[1] *Jaggery* may be defined as the product obtained on concentrating the sweet juice of sugarcane/palm trees with or without prior purification of juices into a solid/semi solid state.

which 0.2 million tons of sugar and 0.5 million tons of *jaggery* is produced per year (BBS, 2003; BSRI, 2003). Out of 0.18 million hectors of sugarcane cultivated land, 0.10 million hectors in sugar mills zones for sugar and 0.08 million hectors in non-mill zones for *jaggery* production. Though about 60% of sugarcane is produced in mills zones areas for sugar production, only 23% -27% is used for sugar and 52% -57% is used for *jaggery* production[2] and rest 10% -12% for seed/chewing purpose.

Table 1.4 Production, demand/supply and import of sugar and *jaggery* in Bangladesh.

Year	Population (million)	Demand for Sugar and Jaggery* ('000 ton)	Sugar production ('000 ton)	Jaggery production ('000 ton)	Sugar Import ('000 ton)	Supply of Sugar and Jaggery ('000 ton)	Deficit ('000 ton)
1990-91	109.6	1425	246	432	138	816	609
1991-92	111.4	1448	195	482	5	682	766
1992-93	113.2	1472	187	415	64	666	806
1993-94	117.7	1530	221	334	86	641	889
1994-95	119.9	1559	270	285	156	711	848
1995-96	122.1	1587	184	371	28	583	1004
1996-97	124.4	1617	135	463	207	805	812
1997-98	126.7	1647	166	415	160	741	906
1998-99	129.1	1678	153	359	191	703	975
1999-00	131.5	1709	123	427	115	665	1044
2000-01	132.0	1716	98	436	328	862	854
2001-02	133.0	1729	205	306	210	721	1008
2002-03	134.0	1742	177	322	600	1099	643
2003-04	134.0	1742	119	450	700	1269	473
2004-05	140.0	1820	106	450	1000	1556	264
2005-06	140.0	1820	133	450	1200	1783	37
Mean	126.0	1640	170	400	324	894	746

* According to FAO recommendation a minimum of 13 kg per capita sugar consumption is required for a balanced human diet and calorie requirement

Source: MIS Report, BSFIC (BSFIC, 2005; BBS, 2006) and (BBS, 2006)

Sugar industry is the second biggest agro-based heavy industry after jute industry in Bangladesh. More than 0.6 million farm-families are dependent on sugar industry for their subsistence. Sugar industry in Bangladesh is owned by the government. At present, 15 sugar mills are in operation under Bangladesh Sugar and Food Industries Corporation (BSFIC) with a capacity of 0.20 million ton of sugar production per year. The industry in Bangladesh is now passing its crisis period due to incurring huge amount of losses every year. The main

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[2] *jaggery* is produces in rural areas using farmer's owned/rented small crusher mostly operated by animal power

causes of losses due to under utilization of sugar production capacity due to inadequate sugarcane supply to the sugar mills, low sugar recovery due to old machineries and wastages, high sugar processing cost incurred due to old technology used and excessive manpower employed in processing and the overall management deficiencies like delay in payment for sugarcane price to the farmer, labour strike and unrest in the industry (Alam et al., 2007).

1.3.5.1 Cultivation Area, Production and Price of Sugarcane and Sugar Production, Recovery and Profit/Loss of Sugar Industry

From the independence of the country in 1971, sugarcane cultivation area in the mills zone is increase a little but the production is increased significantly due to use of modern varieties and technologies (Table 1.5). Sugarcane crushing and sugar production is also increased but not as expected level. Sugar recovery percentages were always unstable. Sugarcane price is determined by the government and it increases gradually farmers' support. After independence in 1971, all heavy industry including sugar industry in Bangladesh is nationalized. After nationalization, performance of the industry was gradually declined. The industry was profitable until the crushing season 1983-84 (except 1972-73). From 1984-85, the industry became a losing concern and losses huge amount every year (except 1989-90 and 1994-95).

1.3.5.2 Production Cost and Sale Price of Sugar and Capacity Utilization of Sugar Industry

Sugar sale price in Bangladesh is determined by the government but the production cost incurred has to bear by the industry. It is observed from the Table 1.6 that production cost is higher than sale price in last 15 years from 1990-91 to 2005-06 (except 1994-95). Capacity utilization of sugar industry is low and highly fluctuated, varied from 47% to 136%[3] in last 15 years. Fluctuating and low capacity utilization indicates poor performance in sugar industry that incurred high processing cost, resulted huge losses every year.

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[3] Annual capacity of sugar factory is the capacity of sugar production within a crushing season of 120 days. In some years, sugarcane production exceeded the crushing capacity of the industry by stipulated period but to protect farmers, sugar factory continue until all the sugarcane has crushed. Note that crushing beyond the season reduces sugar recovery.

Table 1.5 Cultivation area, production and price of sugarcane at mills zone and sugar production, recovery and profit/loss of sugar industry in Bangladesh from after independence of the country (1971-72 to 2005-06).

Crushing Season	Sugarcane Cultivation (ha)	Sugarcane Production (ton)	Sugarcane Crushing (ton)	Total Sugar Production (ton)	Recovery[4] (%)	Sugarcane Price (Tk*/ton)	Profit/Loss (million Tk)
1971-72	55109	1139785	409160	24200	5.92	267.92	
1972-73	47663	1103552	274310	19604	7.14	267.92	-29.95
1973-74	56847	2104241	1187202	89808	7.56	267.92	50.20
1974-75	70970	2206104	1422181	100040	7.02	267.92	50.52
1975-76	50542	1668517	1100946	88177	8.1	267.92	30.27
1976-77	65865	2389199	1706370	140925	8.26	321.51	83.90
1977-78	96022	3271953	2309652	178072	7.72	321.51	6.80
1978-79	75975	2573833	1715505	132812	7.74	321.51	7.40
1979-80	62965	2203112	1272089	94714	7.46	321.51	53.02
1980-81	77370	2833317	1826731	145205	7.93	401.88	262.12
1981-82	94969	3748431	2473301	202158	8.17	401.88	413.08
1982-83	99280	3925136	2216939	181355	8.18	401.88	411.82
1983-84	95902	3388795	1899831	151353	7.97	455.47	422.46
1984-85	94034	3136846	1176599	87849	7.48	509.05	-307.53
1985-86	73789	2998799	1018202	82498	8.11	616.22	-382.68
1986-87	85915	4132368	2286650	181925	7.95	643.01	-397.73
1987-88	94299	4329241	2199389	178260	8.1	643.01	-175.01
1988-89	91866	3767600	1330320	110000	8.27	723.39	-241.30
1989-90	85476	4019565	2096203	193862	8.77	991.31	245.38
1990-91	95459	4695510	3105918	246493	7.93	991.31	-95.94
1991-92	95501	4491122	2390251	195587	8.18	991.31	-655.74
1992-93	87966	4246613	2233114	187483	8.40	991.31	-829.49
1993-94	92250	4576394	2699901	221547	8.21	991.31	-252.51
1994-95	99004	5030449	3482741	270196	7.76	991.31	78.89
1995-96	95942	4340890	2383481	183934	7.71	991.31	-379.28
1996-97	86575	4097854	1763153	135320	7.67	991.31	-659.19
1997-98	88130	4191153	2121845	166457	7.84	991.31	-385.73
1998-99	94352	4123740	2313806	152979	6.61	991.31	-1305.90
1999-00	86397	3526498	1612320	123498	7.66	991.31	-1117.71
2000-01	74873	3361867	1369026	98355	7.18	1098.48	-1352.26
2001-02	88274	4475990	2811123	204329	7.27	1098.48	-1181.19
2002-03	105417	4595268	2633432	177398	6.73	1098.48	-972.49
2003-04	84866	3948244	1642510	119146	7.26	1098.48	-595.80
2004-05	78177	3516972	1414599	106645	7.53	1180	
2005-06	75426	3458042	1853200	133283	7.19	1290	

*Taka is the Bangladesh currency, €1 ~ 90 Taka

Source: MIS Report, (BSFIC, 2005) and (BBS, 2005)

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[4] Recovery percentage is the rate of sugar extraction from raw material

Table 1.6. Capacity utilization, sugar production cost, sale price and profit/loss of sugar industries in Bangladesh (1990-2006)

Crushing Season	Annual Sugar Production Capacity (ton)	Total Sugar Production (ton)	Capacity Utilization (%)	Sugar Production Cost (Tk/kg)	Sale Price (Tk/kg)	Profit/Loss (million Tk)
1990-91	199250	246493	123.71	26.48	27.18	-95.94
1991-92	199250	195587	98.16	28.59	25	-655.74
1992-93	202050	187483	92.79	28.86	25.10	-829.49
1993-94	205050	221547	108.05	27.74	26.50	-252.51
1994-95	198440	270196	136.16	26.77	27	+78.89
1995-96	198440	183934	92.69	30.41	27	-379.28
1996-97	210440	135320	64.30	33.79	27	-659.19
1997-98	210440	166457	79.10	31.65	27.47	-385.73
1998-99	210440	152979	72.70	36.57	27.47	-1305.90
1999-00	210440	123498	58.69	37.19	27.47	-1117.71
2000-01	210440	98355	46.74	45.09	27.47	-1352.26
2001-02	210440	204329	97.10	34.29	27.47	-1181.19
2002-03	210440	177398	84.30	32.92	26.50	-972.49
2003-04	210440	119146	56.62	37	27	-594.80
2004-05	210440	106645	50.68	35	32	
2005-06	210440	133283	63.34	33	42	

Source: MIS Report, (BSFIC, 2005) and (BBS, 2005)

1.3.6. Cost Analysis

Cost of sugar production comprises two parts, one is for sugarcane production and another is for processing expenses. Sugarcane production cost is occurred at farm level where processing cost incurred at sugar industry/factory level. Data have been collected both from primary and secondary sources. Primary data have been collected to investigate farm scenario and cost/return analysis at farm level. Secondary data have been collected from published sources like journals, annual reports etc mostly on sugarcane, sugar and sugar industry of Bangladesh.

1.3.6.1 Cost at Farm Level

Sugarcane is the main raw material for sugar production in Bangladesh. Sugarcane production cost is the cost of sugar at farm level. Sugarcane production cost comprises land preparation expenses, plantation expenses, seed cost, fertilizer expenses, pesticide expenses, intercultural operation like weeding, mulching, de-trashing, tying expenses, harvesting expenses, and transportation expenses. Sample survey technique was used to collect primary data on sugar production cost at farm level.

Selection of Survey Area

Selection of appropriate study area is an important part of sample survey. It depends upon the purpose of the study. Sugarcane grown in Bangladesh is concentrate in west and north-west part of the country (Annexure II). According to the purpose of the study, Natore sugar mills zone area have been selected for the study. This area is in the typical sugarcane producing region of Bangladesh. Out of 15 operating sugar mills in Bangladesh, 2 are located in the Natore district and sugarcane is the main cash crop of the farmer's of the area.

Farm Selection

Sample farm have been selected according to the purpose of the study. Farmers who grown sugarcane in the study area are listed then sample farm have been chosen randomly from the list.

Data Collection

There are several methods of collecting farm data. Selection of particular methods mainly depends on the nature of the research problem, provision of research funds, time constraints etc. Survey methods have been used to collect farm data for this study. Farm survey data covers farming characteristics, costs and returns of sugarcane production etc.

1.3.6.2 Cost Analysis by Operation

Land Preparation Expenses

Land for sugarcane cultivation in Bangladesh prepared by power tiller or bullock operated plough and sometimes by tractor. Most of farmers in Bangladesh do not have power tiller or tractor. There are some power tiller or tractor owners who plough farmer's land on contract basis. Generally farmer use bullock operated plough or plough by power tiller or tractor owner on contract basis. Bullock operated plough is very cheap and negligible as fixed cost. Hence, land preparation expense is virtually a variable cost. Sugarcane cultivation needs about 4-5 times ploughing/ harrowing and laddering. Expenses for land preparation was observed 40 Euro per ha and accounted 6% of total cost incurred (Table 1.7).

Plantation Expenses

Plantation of Sugarcane in Bangladesh is done manually. Sugarcane seed set or seedling is put in deep furrow and covers the set/seedling with soil by human labour, so plantation expense comprise only by human labour. Per ha plantation expense is observed 58 Euro that represents 8% of total production cost (Table 1.7).

Seed Cost

Two or three budded small piece of sugarcane or seedlings is used as sugarcane seed. Upper half or upper 1/3rd of the sugarcane is more suitable for seed/seedlings. Seed cost is a big part of sugarcane production cost. On an average 6.1 tons of seed is needed to cultivate one hectare of land and estimated seed cost is 107 Euro per ha which accounted 15% of total cost (Table 1.7).

Fertilizer Expenses

Sugarcane is an exhausting annual plant and need significant amount of fertilizer for proper growth and yield. Farmers are mostly use Urea, TSP, MP and Gypsum for sugarcane cultivation. They seldom use manure. Per ha fertilizer expense is accounted 87 Euro and it observed about 13% of total cost (Table 1.7).

Pesticide Expenses

Due to containing sugar, sugarcane is highly susceptible to diseases and insect-pest and disease infestation. Humid and worm weather also helps insect-pest to multiply faster. Pesticide expenses are depends on infestation but it is an obvious part of sugarcane production cost. Pesticide expenses are accounted 36 Euro per ha that represents 5% of total cost (Table 1.7).

Intercultural Operation Expenses

Intercultural operations in sugarcane cultivation include weeding, mulching, de-trashing, tying etc. All intercultural operations are done manually. Hence, it is virtually labour expenses. It is a significant part of sugarcane production cost. Per ha intercultural operations expenses observed 109 Euro and represents 16% of total cost (Table 1.7).

Harvesting Expense

In Bangladesh, sugarcane is harvested manually. However, harvesting cost includes only manual labour expense. It is a big part of total cost and per ha harvesting cost is accounted 159 Euro, which represents 23% of total cost (Table 1.7).

Transportation Expenses

Sugarcane is bulky and heavy material. Farmers have to bear transportation expenses from farm to sugar factory or in some cases to sugarcane procurement center of sugar industry. Transportation expense depends on yield of sugarcane and distance from the factory or procurement center. On an average transportation cost per ha is 96 Euro, which accounts for 14% of total cost (Table 1.7).

1.3.6.3 Return from Sugarcane at Farm Level

Return from sugarcane production at farm level is satisfactory to the farmers. Total return and net return per ha is observed 1341 and 650 Euro, respectively (Table 1.7), which is significantly higher than other crops like rice (588 and 389 Euro), vegetables (136 and 89 Euro), potato (131 and 92 Euro) (Anwar, 2008). Cost of production for 1 ton of sugarcane is observed 8.62 Euro and sale price provided by the sugar industry is 16.67 Euro per ton. Hence, farmers are gaining net income of 8.05 Euro per ton of sugarcane production (Table 1.8). Detailed Cost and return of sugarcane production of sample farmers are presented in Appendix I.

Table 1.7 Cost and return of sugarcane production in Bangladesh (per ha)

Cost Items	Cost (Euro)	% of Total Cost
Land preparation	39.92	5.77
Plantation/Transplantation	58.05	8.39
Intercultural Operation	108.70	15.72
Harvesting	158.76	22.95
Seed Cost	107.12	15.49
Fertilizer	87.24	12.61
Pesticide	36.09	5.22
Transportation	95.81	13.85
Total Cost	691.68	100
Total Return	1341.28	
Net Return	649.60	

*Yield of sugarcane observed 80.45 ton per hectare and sale price is Taka 1500 per ton.

Source: Field survey

Table 1.8 Benefit from production of one ton sugarcane at farm level

Items	Cost/Return (Euro)
Sugarcane production cost at farm level per ton	8.62
Sale price of sugarcane per ton	16.67
Net income per ton of sugarcane production	8.05

Source: Field survey

1.3.6.4 Cost at Factory Level

Factory level cost for sugar production can be classified into two parts namely variable cost and fixed cost. Variable cost includes costs for raw material (sugarcane), other material (chemicals etc), seasonal labour, electricity & fuel, repair & maintenance of vehicles. Fixed costs include salary and wages of permanent employee, repair & maintenance of buildings and machineries, interest on loan, depreciation, and administrative expenses. Table 4.6 shows production cost of sugar per kg at factory level. It is observed from the table that production cost of sugar in Bangladesh is 43.43 Eurocents per kg. The major expense is goes to raw material, i.e., sugarcane purchase cost. Out of total cost of 43.43 Eurocents, 22.3 Eurocents is spent for sugarcane and it is accounted 51% of total production cost. The second biggest cost item is salary & wages of permanent employee and it is 9.43 Eurocent per kg of sugar, which accounted 22% of total cost. Among total cost of sugar production, variable cost is calculated 27.61 Eurocents and fixed cost is 15.82 Eurocent per kg of sugar, which accounted for 64% and 36% of total cost, respectively. Except sugarcane price, only process cost of sugar at factory level is 21.13 Eurocents per kg.

Table 4.6. Sugar production/process cost at factory level (per kg)

Cost Items	**Cost (Euro cent)**	**% of Total Cost**
Variable Cost		
Raw material (sugarcane)	22.30	51.35
Other material costs (chemicals, etc.)	0.88	2.02
Seasonal labour	2.80	6.45
Electricity & Fuel	1.06	2.43
Repair & Maintenance of vehicles	0.58	1.33
Total Variable Cost	**27.61**	**63.58**
Fixed Cost		
Salary & Wage	9.43	21.72
Repair & Maintenance of buildings and machineries	1.04	2.40
Interest on loan	2.36	5.42
Depreciation	1.17	2.68
Administrative expenses	1.82	4.20
Total Fixed Cost	**15.82**	**36.42**
Total Production Cost	**43.43**	**100**
Process Cost (except sugarcane cost)	21.13	48.66

Source: Bangladesh Sugar and Food Industries Corporation (BSFIC)

1.3.7 Conclusion

Sugar industry in Bangladesh has significant importance in terms of national GDP contribution, employment generation and foreign currency savings. Though it is the second biggest agro-based industry after jute industry, it satisfies only a small part of home demand for sugar. The industry is now passing its crisis period due to incurring huge amount of losses every year. The main causes of losses due to under utilization of sugar production capacity due to inadequate sugarcane supply to the sugar mills, low sugar recovery due to old machineries and wastages, high sugar processing cost incurred due to old technology used and excessive manpower employed in processing and the overall management deficiencies like delay in payment for sugarcane price to the farmer, labour strike and unrest in the industry. Raw material cost is the major cost of sugar production. Compare to other crops, farmers are gaining satisfactory income from sugarcane selling to the sugar mills but the process cost at factory is very high.

However, sugar production cost in Bangladesh (43.4 Euro cent per kg) seems higher compare to the cost in the major sugar exporting country (34 Euro cent per kg) (Salassi and Deliberto, 2010) but sugar production cost in the Europe is much higher than the world price. European sugar producers are strongly protected by supportive measures like subsidy in quota, tariff, and export subsidy. European support measure and protectionist behavior has criticized and the World Trade Organization panel ruling that found the EU sugar regime is in violation of WTO export commitments (USDA, 2006). Continuous international pressure from different international trade organization and moving from commodity support to direct area payment under 2003 CAP reform led to reform European sugar regime drastically.

CHAPTER II: EU REFORM OF SUGAR CMO AND ITS IMPACT

2.1 CAP Reform and the European Sugar Industry

The European Union (EU) is one of the leading sugar producers and traders in the world. This position was built over time through the application of protectionist policies that regulated all aspects of the industry, ranging from production and prices to exports and imports. The existing EU sugar policy commonly referred to as the Common Market Organization (CMO) for sugar was set up in 1968 to support a fair income to European producers as well as to attain EU market self supply. It featured production quotas, guaranteed prices and arrangements for trade and self-financing.

The creation of a common agricultural policy was proposed by the European Commission. It followed the signing of the Treaty of Rome in 1957, which established the Common Market. The Common Agricultural Policy (CAP) was agreed to at the Stresa conference in July 1958. The CAP established a common pricing system for all farmers in the member countries, and fixed agricultural prices above world market levels to protect farmers in member countries who generally had higher production costs than other world market producers.

The main purpose of the Common Market Organization (CMO) in the sugar sector when it was created in 1968 was to guarantee sugar producers a fair income to provide self-sufficiency in sugar throughout the Community. High prices paid by the consumers encouraged sugar production in Community and import levies were used to deter imports from non-EU countries. The essential features of the sugar regime were a support price (a guaranteed minimum prices to sugar growers and producers to support the market); production quotas to limit production and distribute it across the European community; tariffs and quotas on sugar imports from non-EU countries; and, subsidies to export the surplus of sugar production out of the European Union (OECD, 2007).

Since its creation in 1968, the CMO for sugar has changed only marginally. The first change was in 1975 following the United Kingdom's accession, when the CMO incorporated that country's previous commitments to certain African, Caribbean, and Pacific (ACP) countries to import raw cane sugar for refining and subsequent sale on the UK market. The second big modification came in 1995 following the Uruguay Round, with a restriction on export refunds. The CMO was adjusted by making provision to reduce quotas in the event that the limit on refunds meant that the available surplus on the Community market could no longer be exported with refund. Since then, in practice, if imports increased the market equilibrium was re-established by reducing Community quotas (reduction mechanism) (EC, 2003, 2004).

In the Common Agricultural Policy, the Sugar CMO could only achieve its objectives by means of a combination of instruments (EC, 2004; Elbehri et al., 2008). The first of these instruments is product price support - an intervention price at which EU-mandated agencies step into the market to buy eligible supplies, assuring a floor on the market price.

The second mechanism was the imposition of production quotas. These quotas were distributed for individual Member States, not for all the EU. At the onset of the CMO, two types of quotas were established: quota ‘A’, to cover the market demand, and quota ‘B’, which would be exportable. The expansion of production quickly resulted in the need to create a new quota (C): quota ‘A’ responding to internal demand, quota ‘B’ being exportable with export restitutions (a subsidy on each unit exported) and quota ‘C’ being exportable without any kind of support, and stopped from entering the European market (which would constitute an expansion of supply and depress market prices). Quota ‘C’ is that it may be carried over to the next marketing year, and considered in either quota ‘A’ or ‘B’, therefore attracting subsidies.

The third mechanism was border protection: heavy tariffs were put in place in order to erode the cost advantage of exporting countries. However, not all imports were subject to tariffs: as a result of the UK's admission in 1975, the EU “inherited” set of preferential import agreements, which allow some countries to export a set amount of sugar to the European market free of tariffs. These imports can be re-exported, using the fact that the EU buys them below the prevailing price in the world market, and so helping make up some of the expenditure in export subsidies.

The last mechanism used by the Sugar CMO was export refunds. Because of the large surpluses, the decision was made to subsidize the export into the world market. Since prices inside the European market are much higher than prices prevailing in the world market (from double in 1968 to the triple in 2004), exports of ‘B’ quota sugar were subsidized, in order to allow them to compete in the world market, with the EU refunding.

In terms of the mechanisms used, the first important change was the merger of quotas ‘A’ and ‘B’ and the introduction of quota buyouts (EC, 2005). All exports must come from this A+B quota pool, exports from former quota ‘C’ being forbidden. As a result, quota ‘C’ production will have to be carried on for the following marketing year. A heavy levy has been put in place to penalize overproduction (Mitchell, 2004).

However, CMOs success in making sugar one of the most profitable crops in many EU countries has succeeded in delaying reform proposals until recently. The principal causes for reforming the sugar program at 2005 are threefold: (1) the CAP reforms of 2003/04 moving from commodity support to direct area payments (that left sugar as the only major commodity unreformed); (2) the “Everything But Arms” (EBA)[5] agreement, allowing the 48 least developed countries duty-free access to the EU sugar market by 2009; and (3) a World Trade Organization (WTO) Panel ruling that found the EU sugar regime in violation of WTO export commitments. Additionally, the EU offer to eliminate export subsidies in the Doha Round of WTO negotiations played a role in shaping the reform proposal (USDA, 2006). These events led to the European Commission’s proposal to drastically reform sugar in 2005.

The reform proposals were designed to continue with its recent reforms of the CAP and to meet its international obligations. The stated aims of the reform are (1) to encourage

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[5] EBA is the special arrangements in international trade for least developed countries. It is proved that trade is one of the most effective tools to foster development. Increased trade with developing countries will enhance their export earnings, promote their industrialisation and encourage the diversification of their economies. The classical instrument for achieving these objectives are tariff preferences, which provide an incentive to traders to import products from developing countries and thus help them to compete on international markets.

In 1968, the first United Nations Conference on Trade and Development (UNCTAD) recommended the creation of a "Generalised System Tariff of Preferences" (the acronym “GSP”) under which industrialised countries would grant autonomous trade preferences to all developing countries. The European Community was the first to implement a GSP scheme in 1971. Other countries have subsequently established their own GSP schemes that differ both in their product coverage and rules of origin.

Traditionally, it has been admitted that the group of least developed countries (LDCs) should receive more favourable treatment than other developing countries. Gradually, market access for products from these countries has been fully liberalized. In February 2001, the Council adopted Regulation (EC) 416/2001, the so-called "EBA Regulation" ("Everything But Arms"), granting duty-free access to imports of all products from LDC's, except arms and munitions, without any quantitative restrictions (with the exception of bananas, sugar and rice for a limited period). EBA was later incorporated into the present GSP Council Regulation (EC) No 2501/2001.

reductions in domestic sugar output, particularly in regions with high production costs or lower sugar beet yields; (2) to bring export subsidies in line with WTO commitments; (3) to dampen incentives for EU sugar imports from the EBA countries; and (4) to reduce the price gap between sugar and competing sweeteners to forestall the substitution of sugar. The basic features of the proposal are (EC, 2005):

- Sugar price is reduced by 36 percent over a 4-year phase-in period beginning from 2006/07 (to ensure sustainable market balance, -20 percent in year one, -25 percent in year two, -30 percent in year three and -36 percent in year four).
- Minimum sugar beet price is reduced by 39.5 percent to €26.3/metric ton over the phase-in period.
- Sugar production quotas are not reduced except through a voluntary 4-year restructuring program where quota can be sold and retired. Payments for quota are €730/mt for 2006/07 and 2007/08; €625/mt for 2008/09 and €520/mt for 2009/10.
- Restructuring is financed by quota levies on producers and processors who do not sell quota. Total value of the restructuring fund is projected at €5.704 billion.
- Compensation is available to farmers at an average of 64.2 percent of the price cut. The aid is included in the Single Farm Payment and is linked to payments for compliance with environmental and land management standards.
- Establishment of a prohibitive super levy to be applied to over-quota production.
- Non-food sugar (sugar for the chemical and pharmaceutical industries and for the production of bioethanol) will be excluded from production quotas.

The European Commission estimated that, restricting EU sugar exports to comply with the Panel ruling will require EU production to be reduced by around 2 million Mt. Reduction of sugar production in the EU would occur in the relatively high cost regions of the EU while low-cost regions would be able to increase production by virtue of the restructuring components of the proposal. According to EU Commission estimates, the high cost regions of growing and processing sugar beets where drastic reduction in sugar beet production is expected are in Greece, Ireland, Italy, and Portugal; member states where production is expected to be reduced significantly are Czech Republic, Denmark, Finland, Hungary, Spain, Latvia, Lithuania, Slovakia, and Slovenia; and member states where production is expected to fall marginally are Austria, Belgium, France, Germany, Netherlands, Poland, Sweden, and the United Kingdom.

2.2 Sugar Production in Europe and Impacts of Reform

In the Europe the first and second largest sugar producing countries are France and Germany, account for about half of the EU-25's production, followed by Poland, the UK, and Italy (Table 2.1). Sugar production in Europe was stable for first five years of the decade between 18-20 million tones. In the year 2006/07, sugar production in Europe reduced significantly (17.5%). The Ireland has completely stopped sugar production. Latvia and Slovenia have stopped sugar production from 2007/08. Portugal stopped sugar production from sugar beet from the year 2008/09 (CEFS, 2009).

Strong support and protection given to the EU sugar sector had many different results. First, the EU became a net exporter of sugar as the supply expanded well beyond the demand. By driving a wedge between world market prices and prices prevailing inside the EU, the Sugar CMO originates a transfer of wealth from consumers to producers and refiners. Also, since the excess production was exported with refunds, sugar producers received the same revenues as they would selling the sugar inside the EU market. Such subsidized exports depressed world market prices, making other producers worse off.

The new Common Market Organization in the sugar sector, which began in effect from July 2006, includes progressive reduction of prices of sugar and sugar beets as well as the reduction of quotas of sugar for each of EU country. These developments affected beet production dramatically, due to the sugar beet cultivation becoming economically disadvantageous and the sugar industries decreasing their production. According to estimates by the European Commission, total EU sugar production should fall to 12.2 million tons per year, which is equal to a decline of 43 per cent from the 2005 base year (EC, 2005). To achieve the target, based on estimates of the combined profitability of the industry (growers & manufacturers) the commission classified EU-25 sugar producing Member States into three groups, depending on their level of costs.

- Member States where sugar production is likely to be drastically reduced or even phased out: Greece, Ireland, Italy, Portugal;

- Member States in the border zone: Czech Republic, Spain, Denmark, Latvia, Lithuania, Hungary, Slovakia, Slovenia and Finland. In these MS, production is likely to be maintained but at a significantly lower level;
- Member States where the decrease in sugar production will be limited. It is even likely that overall production would not decrease in some MS: Austria, Belgium, France, Germany, the Netherlands, Poland, Sweden and the UK.

If Member States in group (1) fully abandoned production, this would represent a 9% drop compared with EU-25 quota sugar production in 2003/04. However, it is not excluded that some factories would remain in business. Within the "borderline" group (2) some factories will close down, while others will stay in business and try to increase their production. In fact, some member states could have been classified under group (3). For instance Denmark could have been considered alongside Sweden, as there are economic links between factories in these Member States. Factory ownership and the related restructuring and implementation policy have also influenced the classification of Finland. Member States in group (3) will on the one hand undergo a limited reduction in production under quota but, on the other, will narrow down their C sugar production. Member States in group (3) are expected to remain competitive even at reduced intervention prices.

The main achievements of the first three years (2006 until 2009/10 (provisional status on January 2009)) of the restructuring is 5.77 million tones of quota renounced and out of 184 sugar factories, 79 have closed (Barjol, 2008; Ruiz, 2009). Though the price for the consumer remained the same, the price for the producer reduced. According to EBA initiative there has been a reduction of import duties on sugar by 20% on 1 July 2006, by 50% on 1 July 2007, and by 80% on 1 July 2008 until their entire elimination on 1 July 2009 (EC, 2005). In this situation the reference price has been dramatically reduced from €631.9 to €541.5 per ton from 1st of October 2008. Considering quota and duty free entrance of LDCs country to the EU market, the reference price from 1st of October 2009 was fixed €404.4 per ton (Barjol, 2008).

Table 2.1. Sugar (white sugar) production in EU countries last five years (‘000 tons)

	2004/05	2005/06	2006/07	2007/08	2008/09	Variation 08/09-07/08
Group-1						
Greece	259.3	310.3	196.6	78.4	100.4	28.1%
Ireland	213.2	205.2	-	-	-	-
Italy	1,158.2	1,804.4	657.1	700.3	455.0	-35%
Portugal	74.4	37.2	25.0	14.2	-	-100%
Group-2						
Denmark	471.5	475.0	375.0	380.0	397.0	4.5%
Finland	206.7	230.7	180.6	101.0	69.5	-31.2%
Spain	1,061.0	1,086.0	1,040.0	711	608	-14.5%
Czech Republic	558.4	558.9	470.5	353.9	414.6	-17.2%
Hungary	499.4	490.8	348.5	226.4	104.2	-29%
Latvia	66.5	71.0	43.4	-	-	-
Lithuania	131.1	126.4	96.6	124.5	64.5	-48.2%
Slovakia	233.0	237.5	216.9	145.8	108.8	-25.4%
Slovenia	35.3	46.9	43.4	-	-	-
Group-3						
Austria	458.1	488.9	407.6	379.4	438.8	15.7%
Belgium	990.6	925.3	855.6	875.0	724.6	-17.2%
France	4,435.1	4,410.0	4,451.0	4, 619.9	4,024.2	-12.9%
Germany	4,334.2	4,040.6	3,262.2	3,905.8	3,638.4	-6.7%
The Netherlands	1,037.9	976.15	872.0	907.9	903.7	-12.8%
Poland	2,001.4	2,054.0	1,706.8	1,919.5	1,389.1	-27.6%
Sweden	372.4	406.4	314.0	354.0	327.0	-7.6%
United Kingdom	1,390.0	1,340.9	1,157.4	1,049.2	2,278.6	117.2%
EU-25 Total	20,022.3	20,322.7	16,768.3	16,891.8	16,388.2	-3.0%

Source: Sugar Statistics 2009, Comité Européen des Fabricants de Sucre (CEFS).

2.3 Impacts to the World Market

Because the EU is the world’s third largest producer, the second largest consumer and the third largest importer of sugar, the EU sugar reforms have important consequences for global sugar markets. Changes in the EU net trade position have a significant impact on the world market equilibrium. Along with internal reform, the sector has recently been subject to intense pressure by multilateral negotiations, especially WTO negotiations in significant tariff cuts in the sugar sector, as it has been agreed that the most protected products will face higher cuts (WTO, 2004). The agreement to ban export subsidies by 2013 adds some longer-term constraints on the EU sugar regime (WTO, 2005). These pressure have already led to major changes in sugar policies (Gohin and Bureau, 2006).

Several studies have been undertaken to investigate the effects of changes in sugar policies and multilateral trade liberalization. The different studies provide results that are largely inconsistent, even for rather similar scenarios. Some authors find that market liberalisation will result in large welfare gains and significant changes in international trade. Others believe that the overall gains will actually be limited due to inelastic demand, persistence of supply control (production quotas) and large rents that need to be reduced before reforms actually become binding and affect output (Gohin and Bureau, 2006). Some authors have found that even a partial liberalisation in the sugar market will generate a very large increase in world prices (Elobeid and Beghin, 2005). (Busse and Jerosch, 2006) reported that total EU exports are expected to fall by 4 million tons. After the complete removal of all import restrictions for least-developed countries, imports from these countries are expected to increase by up to 2.2 million tons, whereas total imports may rise by 3.9 million tons. The combined effect of cuts in prices and production quotas will lead to lower EU sugar production, lower prices for consumers, and higher consumption.

2.4 Sugar Overview and Perspectives in Greece

According to the assessment of the European Commission, cost of sugar production in Greece is high (EC, 2005). The Commission estimated average breakeven price at which level sugar beet becomes less profitable than competing crops (wheat, barley, maize, durum, and sunflower). Break-even price is the price level at which, on average, the farmer decides to switch from sugar beet to other crops. The estimates for break-even prices were then compared with the minimum price proposed for sugar beet under full implementation of the reform is € 25/t but the break-even price of sugar beet in Greece is € 34/t. Though the average sugar beet yield in Greece is higher than the EU-25 average yield but both the average sugar content in beet (%) and sugar yield per hectare is significantly lower than EU average (Table 2.2). The Commission mentioned that both the farm sector and the processing industry in Greece are less efficient than the EU average and suggested to reduce sugar production drastically (EC, 2005). According to the Commission's suggestion, the Hellenic Sugar Industry[6] decided to reduce their sugar production by 50% that is about 160 thousands tones of sugar. The industry has also decided to transform 2 sugar plants (out of 5) for alternative use like bioethanol production using sugar beet, molasses and wheat.

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[6] Helenic Sugar Industry owned by the government of Greece and is the monopoly authority to produce sugar in Greece.

Sugar in Greece is produced from sugar beet. On average 40 thousand hectares of sugar beet is harvested each year for sugar production and about 300 thousand tons of sugar is produced each year (Table 2.2). From the year 2007/08, both the beet area for sugar and production of sugar are reduced drastically (CEFS, 2009).

Table 2.2. Sugar and sugar beet productivity in Greece last ten years.

Year	Beet area for sugar (‘000ha)	Sugar beet yield (t/ha)	Average sugar content in beet (%)	Sugar yield (t/ha)	Sugar production (‘000 tones)
1998/99	36.6	52.4	14.5	7.2	200.0
1999/00	39.2	55.1	13.5	5.9	231.7
2000/01	50.0	62.9	14.5	7.4	367.6
2001/02	42.2	66.9	14.2	7.5	314.3
2002/03	40.9	73.1	12.7	7.2	295.6
2003/04	39.1	50.7	13.2	5.2	205.0
2004/05	32.9	65.6	14.7	7.9	259.3
2005/06	42.0	66.3	14.0	7.4	310.3
2006/07	26.9	61.3	13.2	6.3	196.6
2007/08	13.7	56.7	13.4	5.7	78.4
2008/09	13.8	65.2	14.0	7.2	100.4
Average (last five year)		63.0	13.86	6.9	
EU-25 average (last five year)		58.3	17.2	9.3	

Source: Sugar Statistics 2009, Comité Européen des Fabricants de Sucre (CEFS).

2.4.1 Non-food Sugar in Greece

In the basic regulation of CMO, sugar for certain industrial uses is not included when calculating production. That sugar is considered non-CMO sugar and so does not qualify for any CMO measure and there is no limit on its production. This provision has applied since the start of the CMO to sugar processed into alcohol, including fuel ethanol, rum or spreadable syrups (e.g. Rijnse appelstroop). Since 1 February 2004 it has been extended to sugar used to produce yeasts. While this provision has had limited effect up to now, it is of fresh interest given the prospects offered by Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport (EC, 2004).

This arrangement provides some other opportunities for the sugar sector. For instance, sugar beet should qualify for set-aside payments, when cultivated as a non-food crop, and also be made eligible for the energy crop aid of € 45/ha provided for under the 2003 CAP reform. However, sugar beet will compete with cereals for bioethanol (EC, 2005).

CHAPTER III: BIOFUELS

3.1 General Information

Biofuels can be defined as any kind of fuels derived from biological sources. The term biofuel is referred to as liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. A variety of fuels can be produced from biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane. Liquid biofuels are primarily used to fuel vehicles, but can also fuel engines or fuel cells for electricity generation (Demirbas and Balat, 2006).

The concepts of biofuel have been emerged as the main alternative of fossil fuel in the transportation sector. Growing concerns about climate change, high dependence on oil, and increasing oil prices has been promoting biofuel as the main option to displace fossil fuels in transportation (Malça et al., 2005).

Currently, two different types of biofuels represent the bulk of biological transport fuels around the world: ethanol and biodiesel. Both ethanol and biodiesel can be produced from a wide range of feedstock. Ethanol is usually produced from sugar and starchy crops where biodiesel is produced mainly from oil-seed crops, including rapeseed, palm and sunflowers. Other crops and organic wastes can also be used (IEA, 2006).

3.2 Ethanol

Ethanol or ethyl alcohol, is a clear, colorless, flammable liquid that could be used as a fuel or in various industrial uses. According to EU directive, ‘bioethanol’ can be defined as the ethanol produced from biomass and/or the biodegradable fraction of waste, to be used as biofuel (EU, 2003). Ethanol is the most common biofuel, accounting for more than 85% of the total biofuel uses, and the most amount of ethanol has been produced in the sugar industry. Ethanol is typically blends with gasoline in order to expand the gasoline supply, increase the octane rating of gasoline, and make gasoline a less polluting, cleaner burning fuel. Internal combustion engines optimized for operation on alcohol fuels are 20 per cent more energy-efficient than when operated on gasoline (Johansson et al., 1992), and an engine designed specifically to run on ethanol can be 30 per cent more efficient (EPA, 1990).

Bioethanol has been increasingly used in spark ignition engines due to the following three main features: It was originally used as a gasoline extender, displacing gasoline derived from imported crude oil, in particular when oil prices boosted after the oil shocks of 1973 and 1979. Secondly, as a result of the phasing out of leaded fuel, bioethanol became popular as a high-quality octane enhancer. Due to its better anti-knock characteristics, bioethanol provides a valuable additive to mid-to-low-octane gasoline, replacing benzene and other toxic chemicals often used by gasoline refiners as octane enhancers. Thirdly, owing to environmental concerns, bioethanol is used as an emission reducing oxygenate (oxygen-rich compound). In fact, adding bioethanol to gasoline increases the oxygen content of the fuel, improving the combustion of gasoline and reducing the exhaust emissions normally attributed to imperfect combustion in motor vehicles, such as carbon monoxide and unburned hydrocarbons (HABITAT, 1993; Hasan, 2003).

Bioethanol can be used as a fuel for spark ignition engines both in its pure form or blended with gasoline in several proportions (5%, 10% and 85%). Bioethanol can also be used as a component for production of the oxygenate ETBE, which is synthesized from bioethanol and isobutylene, a refinery by-product. In Brazil, bioethanol is used as neat ethanol in 100% alcohol-fuelled passenger cars or is blended with gasoline in proportions of usually about 22% (Calle and Cortez, 1998). In several states of the USA, a small amount of bioethanol (10% by volume) is added to gasoline, known as gasohol or E10. Blends having higher concentrations of bioethanol in gasoline are also used, e.g. in flexible-fuel vehicles that can operate on blends of up to 85% bioethanol (E85). In Europe, Sweden uses bioethanol (i) blended directly with gasoline up to 5% by volume E5; (ii) in the form of E85 in modified light-duty vehicles and (iii) as a diesel replacement in trucks and buses, with ignition improvement additives. Unlike Sweden, in other European countries, e.g. France and Spain, bioethanol is mainly converted to bioETBE, which is used in spark ignition engines in proportions of up to 15% by volume (Malca and Freire, 2006).

Bioethanol from cereals produces a second important by-product, a protein-rich animal feed called Dried Distillers Grains with Soluble (DDGS). For every ton of cereals used for ethanol production on average one third will enter the animal feed stream as DDGS. Because of its high protein level it is very much favoured as replacement of soy cake. Replacing soy by

DDGS has the additional effect of less soy imports and consequently less land being used for growing soy.

3.2.1 Production Process of Bioethanol

Several processes exist for the production of bioethanol. Currently, in Europe processes using sugar beets or grains as raw material are used, but using residual starch streams is gaining increased attention. Whether corn/maize, wheat, sugar beet, sugarcane or woody biomass (lignocellulose) is the feedstock, the final stage of ethanol production is fermentation. The difference with these varying feedstock is how the starch, sugar or cellulose is extracted.

3.2.1.1 Bioethanol production from sugar beet

The production process of ethanol from sugar beet is simpler than from wheat as the sugars are readily available for fermentation. The production of ethanol from sugar beet comprises two main steps. Firstly, feedstock preparation, including washing to remove mud, stones and other waste material, beet slicing and diffusion to obtain green/diffusion juice. Secondly, juice fermentation, distillation to increase ethanol concentration and dehydration to obtain anhydrous ethanol (Malça et al., 2005; SenterNovem, 2006). Production process flow of ethanol from sugar beet is illustrated in Figure 3.1.

Extraction

Extraction is the process of receipt of sucrose from fragmented beets. After cleaning, washing and chopping, beet slice passed into a ‘diffuser’ to extract the sugar into a hot water solution. The liquid exiting the diffuser is called ‘raw juice’. In a combined sugar/bioethanol production process, sugar is extracted from the raw juice. At a certain point, further sugar extraction is not economically attractive. The remaining syrup (‘molasses’) contains 45 wt% sugar, and can be fermented to ethanol. The remaining pulp contains 95% moisture and can be pressed to recover sugar, which is added to the raw juice.

Alternatively, sugar syrup may be produced directly from sugar beet by cooking shredded sugar beet for several hours and then pressing the resulting beet mash and concentrating the juice. The raw juice can be used for production of sugar or bioethanol (Figure 3.1).

Fermentation

Fermentation in general is the metabolic activity at which organic substance is undergo chemical changes with the effect of ferments that excrete by micro-organisms. Industrial fermentation of sugar to ethanol is generally performed with the yeast. The fermentation takes place in large cylindrical fermentors, generally in a batch process, for periods of 10-60 hours. Following fermentation the yeast and other solids are often separated by centrifugation, and may be recycled to the fermentor.

Fermentation can also be executed as a continuous process using continuous stirred tank reactors, which has several advantages over a batch process. Continuous processes may be carried out for a long period without shutdown, have higher productivity and thus require smaller reactor volumes. Continuous fermentations can be fully automated and operated under conditions that give a uniform product. However, a continuous process does require raw materials with uniform quality, as conditions cannot be adapted easily.

Distillation

Afterwards the fermentation, the juice is supplied to the system of distillation for recuperation of ethanol. In this stage the juice contains about 10 - 14% alcohol, water as well as all the non-fermentable solids from the beet and yeast cells. The mash is then be pumped to the continuous flow, multi-column distillation system where the alcohol is removed from the solids and the water. In this classic distillation process the highest level of ethanol concentration can be achieved at about 96% due to the water / ethanol azeotropic system. Therefore, the remaining water has to be removed with a different technique, such as dehydration with molecular sieves.

Dehydration

In order to be used as a component in blends with petrol, bioethanol has to be purified to more than 99.5 vol% purity. To remove the remaining water the ethanol from classic distillation then passes through a dehydration system. Most ethanol plants use a *molecular sieve* to capture the last bit of water in the ethanol. Afterwards the dehydration, the anhydrous ethanol is condensed and stored.

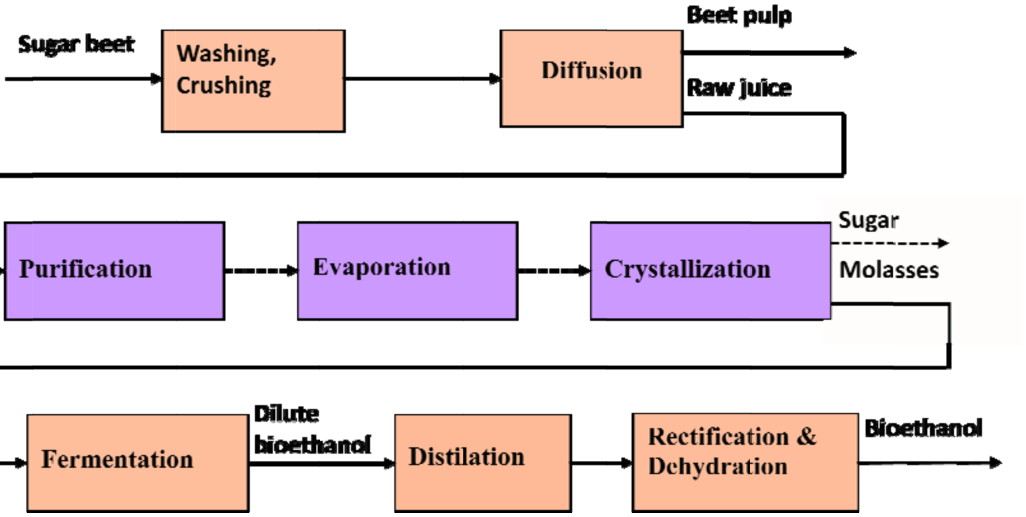

Figure 3.1. Scheme of a combined sugar/bioethanol production process from sugar beet.

3.2.1.2 Bioethanol Production from Wheat

Ethanol processes based on starch are more complicated than those using sugars directly, because the starch has to be hydrolysed to glucose prior to fermentation. The most common process used in Europe is the 'milling and mashing process at higher temperatures'. In this process, first starch is released from the cell material (‘liquefaction’) and then the starch is converted to fermentable sugars ('saccharification') by addition of enzymes (amylases). Production process flow of ethanol from wheat is illustrated in Figure 3.2.

Milling

Wheat grains (rye and barley also) typically contain 60 - 70% wt% starch. The starch is a polysaccharide from which ethanol can be produced with proper treatment. To bring it in process the wheat first passes through hammer mills (or roller), which grind it into a fine powder called meal.

Liquefaction

The meal is then mixed with water to form a "mash". The enzyme alpha-amylase is added, and heat is applied at this stage to enable liquefaction. Alpha-amylase is ferment, which contributes in the split of starch in dextrin. High temperature cooking (120-150 ºC) and a lower temperature holding period (95 ºC) eliminate bacteria before fermentation.

Saccharification

The mash is then cooled in 60-65 ºC and the secondary enzyme (gluco-amylase) is added who causes hydrolysis dextrin to maltose and then in glucose. The mash is cooled down further to the temperature required for fermentation. The performance of this process depends on the efficiency to break up cells during milling and on the efficiency of the enzymes used. The process can be executed as a batch or as a continuous process.

Fermentation - distillation – dehydration

After the starch is converted to glucose, the mashes are fermented to ethanol. The stages of fermentation, distillation and dehydration are the equivalents of production of ethanol from sugar beets that described previously. For the reduction of cost and restriction of superinfection and time of production of ethanol, simultaneous saccharification and fermentation or even simultaneous saccharification, yeast culture and fermentation can be achieved (Figure 3.2).

By-products

Sugar beet pulp is the most important by-product of the sugar beet conversion process. Generally the pulp is pressed and dried and sold as animal feed. It can be added to an anaerobic digester, producing biogas. It can be dried and burnt for process heat. The pulp can also be converted into more ethanol by simultaneous saccharification and fermentation. The purification step also produces foams that are used as organic fertilizer. Vinasses, another co-product from ethanol distillation of green syrup, are concentrated and spreaded on agricultural land (Malca and Freire, 2006).

In the process of ethanol production from wheat, the leftover residue from the fermentation process (Distiller's Dried Grains with Solubles, DDGS) is the wheat equivalent of pulps from sugar beet but with higher protein content and can be sold as high-protein animal feed.

Carbon dioxide (CO_2) is formed in both bioethanol from sugar beet and bioethanol from wheat process as a by-product of the fermentation process. This off-gas stream (>90 vol%

CO_2) contains appreciable amounts of ethanol vapor, which is recovered by scrubbing. In some ethanol plants the CO_2 is captured and marketed for application in soft drinks or Enhanced Oil Recovery (SenterNovem, 2006).

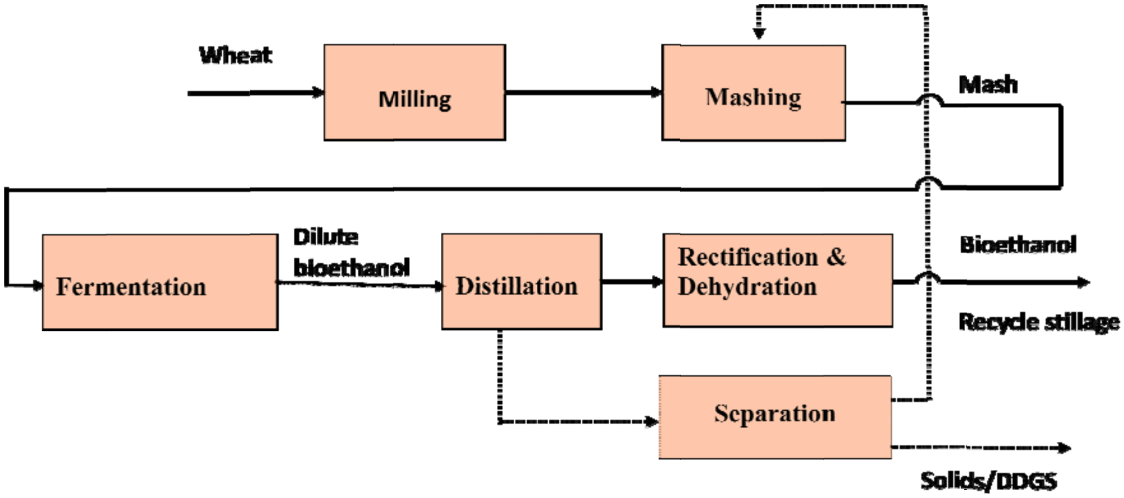

Figure 3.2. Scheme for bioethanol production process from wheat.

3.3 Present Status and Future Projection of Biofuel in Global Context

Both of ethanol and biodiesel, the two main liquid biofuels have started to penetrate the transportation sector in all major regions of the world. The production of ethanol has grown at a compound annual growth rate (CAGR) of 11% over the last five years, with a primary market in the U.S., while biodiesel production has grown at 20% over five years, with a primary market in Europe. Biofuel consumption around the world is projected to grow as much as 14% annually by the International Energy Agency (IEA). Major oil and gas companies are investing hundreds of millions of dollars in biofuel development to match the advances of localized industry and research in developing this sustainable energy source.

Global production of biofuels amounted to 20 Mtoe (Million tons of oil equivalent) in 2005 - equal to about 1% of total road- transport fuel consumption in energy terms. Brazil and the United States together account for almost 80% of global supply (Table 3.1). In both countries, ethanol accounts for almost all biofuels output. US output of ethanol derived mainly from corn (maize), where in Brazil, production of ethanol, entirely based on sugarcane. Production of biofuels in Europe is growing rapidly thanks to strong government initiatives. The bulk of EU production is biodiesel, which in turn, accounts for 87% of world biodiesel output. Elsewhere, China and India are the largest producers of biofuels, mostly in the form of ethanol (IEA, 2006).

Table 3.1. Biofuels production by country (Mtoe)

	Ethanol	Biodiesel	Total
Brazil	8.17	0.05	8.22
United States	7.50	0.22	7.72
European Union	0.48	2.53	3.01
China	0.50	-	0.51
India	0.15	-	0.15
Canada	0.12	-	0.12
World	**17.07**	**2.91**	**19.98**

Source: World Energy Outlook 2006, International Energy Agency.

The IEA projected biofuels production and consumption for the year until 2030 on the basis of reference scenario[7] and alternative policy scenario[8] (IEA, 2006). By 2030, global energy use in road-transport sector is expected to be 55% higher than in 2004 in the reference scenario and 38% higher in the alternative policy scenario. In the reference scenario, total production of biofuels is projected to climbe 20 Mtoe in 2005 to 42 Mtoe in 2010, 54 Mtoe in 2015 and 92 Mtoe in 2030. The average annual rate of growth is 6.3%. To meet this demand, cumulative investment in biorefineries of \$160 billion over 2005-2030 is needed. In the alternative policy scenario, production rises much faster, at 8.3% per year, reaching 73 Mtoe in 2015 and 147 Mtoe in 2030. Cumulative investment totals \$225 over the projection period (Table 3.2).

In both scenarios, the biggest increase in biofuels consumption occurs in the United States – already the world's largest biofuel market – and the Europe, which overtakes Brazil as the second-largest consuming (and producing) region before the end of the current decade. Biofuels use outside these regions remains modest, with the biggest increase occurring in the developing Asia.

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[7] The Reference Scenario takes account of those government policies and measures that were enacted or adopted by mid-2006, though many of them have not yet been fully implemented. Possible, potential or even likely future policy actions are not considered.

[8] The Alternative Policy Scenario analyses how the global energy market could evolve if countries were to adopt all of the policies they are currently considering related to energy security and energy-related CO_2 emissions. The aim is to understand how far those policies could take us in dealing with these challenges and at what cost.

Table 3.2. World biofuels consumption by scenario (Mtoe)

	2004	2010		2015		2030	
		RS	**APS**	RS	**APS**	RS	**APS**
United States	6.8	14.9	16.4	19.8	27.5	22.8	42.9
Europe	2.0	14.8	16.4	18.0	21.5	26.6	35.6
Brazil	6.4	8.3	8.6	10.4	11.0	20.3	23.0
China	0.0	0.7	1.2	1.5	2.7	7.9	13.0
India	0.0	0.1	0.1	0.2	0.3	2.4	4.5
Indonesia	0.0	0.2	0.3	0.4	0.6	1.5	2.3
Asia (others)	0.0	0.9	3.0	1.6	4.9	4.3	13.0
Africa	0.0	0.6	0.7	1.1	1.2	3.4	3.5
Pacific	0.0	0.3	0.8	0.4	1.4	1.0	2.9
Canada	0.1	0.6	1.0	0.7	1.3	1.3	2.8
Others	0.2	0.1	0.3	0.3	0.6	0.9	3.2
World	**15.5**	**41.5**	**48.8**	**54.4**	**73.0**	**92.4**	**146.7**

Note: RS = Reference Scenario, APS = Alternative Policy Scenario
Source: (IEA, 2006)

3.4 Government Support Measures for Biofuels in Selected Countries

A growing number of governments are actively supporting the development of the biofuels sector in recognition of the environmental benefits and energy-securing benefits from reduced oil imports and more desire source of energy supply. Although national circumstances vary markedly, in every country that has managed to develop a sizable biofuel industry, strong government supports has been required to kick-off the industry and bridge the gap between the market value of the fuel and its production cost. Government support can take various forms, including direct financial assistance to biorefiners and retailers in the form of grants, tax credits or cheap loans, subsidies to farmers, tax exemptions for flex-fuel vehicles and tax exemptions or rebates for biofuels. A number of countries have also set targets for the percentage and quantity of biofuels to be used in pure form or blended with conventional fuels. In some countries, fuel retailers are obliged to market particular blends, such as E20 in Brazil (IEA, 2006).

Brazil

Brazil has targeted 40% rise in production of ethanol by volume in 2005-2010 (IEA, 2006). Blending ratio is targeted as 25% of ethanol with gasoline (E25) in 2007; 2% blend of biodiesel with diesel (B2) in early 2008, 5% by 2013 (Coyle, 2007). To achieve the target the government provides tax incentives for oil-seed production, loan assistance and reduced level of industrial tax as production incentives. To provide consumption incentives, tax has exempted for vehicle able to use E-blends and flex-fuel vehicles. Price control and fuel tax advantages also providing over petrol.

USA

Government support for biofuel is provided at all stages of production and consumption in the USA. Crop and irrigation subsidies for feedstock production, subsidies to intermediate inputs, subsidies for production of biofuels through tax credits, tax exemptions and market price support, subsidies for storage and distribution infrastructure, subsidies for the purchase of biofuel, subsidies for the purchase of, or operation of, a vehicle even subsidies to by-product consuming industry (Koplow, 2007).

Support is often delivered through overlapping policies of federal, state and municipal jurisdictions. At the federal level, the largest contributor remains excise tax credits provided to biofuel blenders. Total government support for biofuels in the United States reached approximately $ 6.3–$ 7.7 billion in 2006, the majority of which was directed to ethanol. Over the 2006–12 period, estimated credits worth $ 48 billion in subsidies to the ethanol sector and nearly $ 5 billion will provide in support to biodiesel (Koplow, 2007).

The Energy Policy Act (EPACT) of 2005 established a Renewable Fuels Standard (RFS), requiring use of 28.4 billion liters (7.5 billion gallons) of biofuels by 2012; proposals to raise renewable fuel standard to 36 billion gallons by 2022 (PECC, 2006; Coyle, 2007). At the state level, Iowa targets an ethanol blend of 10 percent in 2009 and 25 percent in 2019. The Missouri Renewable Fuel Standard Act requires that all gasoline sold in Missouri contains at least 10 percent agriculturally derived, denatured ethanol by volume. Hawaii, Montana and Minnesota require that petrol must contain 10 percent ethanol. Washington State requires petrol and diesel to contain 2 percent renewable fuel.

Production is promoted with US$0.135 per liter federal tax credit on ethanol production and US$0.143 per liter tariff on imported ethanol. EPACT provides petrol station owners a 30 percent tax credit up to $30,000 to install pumps and tanks for E85. At the consumption level, tax credit is provided for vehicles run by biofuels and fuel tax has exempted. Subsidies on flex-fuel vehicles and loan assistance have been provided.

Canada

In May 2006, the government announced a Renewable Fuels Strategy, which includes a 5% biofuels use target by 2010 (approximately 3 billion liters) (PECC, 2006). By this period share of bioethanol in total road-fuel consumption is targeted 3.5% by volume (IEA, 2006). Excise tax has exempted and some provinces exempted ethanol from road tax also. The federal government provides a fuel excise tax exemption of C$0.10/liter for ethanol, and C$0.4/liter for biodiesel. The federal government is providing capital assistance through the Ethanol Expansion Program (EEP).

Sweden

Sweden has targeted 3% share of biofuel by energy content in total road-fuel consumption by 2005 and 10% by 2020. To achieve the target, tax incentives for new plants, access to EU Common Agricultural Policy provisions, and capital grants have been provided as production incentives. Fuel excise duty on biofuels is exempted as consumption incentives.

France

Share of biofuels in total road-fuels consumption by volume is targeted 5.75% in 2008; 7% in 2010; and 10% in 2015 (IEA, 2006). France is implemented liquid biofuel support programs from 1993 through a fixed tax exemption. The current tax credits are 25 Euros/hl for biodiesel and 33 Euros/hl for ethanol. Tax credits are also provided on equipment using renewable energy. On the other hand tax penalty is imposed on refiners not using biofuels. Access to EU Common Agricultural Policy provisions, and capital grants have been provided as production incentives. Fuel tax is exempted at consumption level.

Germany

In July 2002 an amendment to the mineral oil law was adopted, within which the exemption of all biogenic fuels from the mineral oil tax was explicitly stipulated for the first time. This law was amended slightly a year later, adjusting it to the EU biofuels directive, which had been adopted in mid-2003. These tax law changes together with the tax raise for fossil fuels led to a massive rise in German biofuel production and consumption. The share of biofuels in the German fuel market reached years up to 6.3% by the year 2006 (Vogelpohl, 2010). Until 2006, the producers of biofuels benefited from a total tax exemption for any kind of biofuel. In 2006, however, the German parliament adopted the introduction of a tax on biofuels, while at the same time setting up a mandatory biofuels quota. Consequently, the share of biofuels in total EU fuel consumption in the transport sector rose to 2.6% in 2007, with Germany being the frontrunner with a share of 7,3%, and is expected to further increase. Access to EU Common Agricultural Policy provisions, capital grants have been provided as production incentives.

UK

Government has announced Enhanced Capital Allowances (ECAs) as a measure to support investment in biofuels production facilities. The government also declared Renewable Transport Fuel Obligations (RTFO) (Amendment) Order 2009, requires suppliers of fossil fuels to ensure that a specified percentage of the road fuels they supply in the UK is made up of renewable fuels. The obligation period beginning from 15th April 2008, the specified amount was the amount equal to 2.564% in volume. The percentage specified with an increasing amount every year. For the obligation period beginning on 15th April 2012, the specified amount is an amount equal to 4.712% of that volume. For each subsequent obligation period, the specified amount is an amount equal to 5.263% of that volume (RTFO, 2009). Access to EU Common Agricultural Policy provisions, and capital grants have been provided as production incentives. Fuel excise has exempted partly for biofuels.

India

Government of India declared National Policy on Biofuels. The Goal of the Policy is to ensure a minimum level of biofuels become readily available in the market to meet the demand at any given time. An indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2017 is proposed. Ten percent mandatory blending of ethanol with gasoline is become effective from October, 2008 in 20 States and 4 Union Territories. Bio-ethanol already enjoys concessional excise duty of 16% and biodiesel is exempted from excise duty. No other Central taxes and duties are proposed to be levied on bio-diesel and bio-ethanol. Custom and excise duty concessions would be provided on plant and machinery for production of bio-diesel or bio-ethanol, as well as for engines run on biofuels for transport, stationary and other applications, if these are not manufactured indigenously (National Policy on Biofuels, Government of India).

Japan

Japan's government has promoted low-level ethanol blends in preparation for a possible blending mandate, with the long-term intention of replacing 20 percent of the nation's oil demand with biofuels or gas-to-liquid (GTL) fuels by 2030. In June 2006, Japan's Environment Ministry announced intentions to require biofuels account for 10 percent of transportation fuels by 2030. Since feedstock supplies are limited Japan, the government will promote close ties with Brazil as a source ethanol imports. Japan is promoting production of biodiesel from used vegetable oil to be blended with for use by public buses, official cars, and municipal garbage trucks (PECC, 2006).

China

China is the third-largest ethanol producer in the world, after the United States and Brazil. It is in the midst of a $5 billion, 10-year programme to expand ethanol production as part of a broader effort to raise the energy share of renewables (biofuels, nuclear, hydroelectric and solar power) from 7 percent to 16 percent by 2020 to meet growing energy demands and environmental challenges (PECC, 2006). To accelerate production, $200 million has allocated in research and development of biofuels. Loan assistance and various direct subsidies, including tax exemptions have been provided.

According to government data commissioned by the Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD), China provided a total US$ 115 million, roughly US$ 0.40 a litre in biofuel subsidies in 2006. These comprised support for ethanol in the form of direct output-linked subsidies paid to the five licensed producers, as well as tax exemptions and low-interest loans for capital investment. Further support is provided through mandatory consumption of ethanol-blended fuel (a ten per cent blend with gasoline, E10) in ten provinces (GSI, 2008).

Thailand

Thailand, the world's second-largest sugar exporter after Brazil, targeted 2% share of bioethanol in total road fuel consumption by volume by 2010 (IEA, 2006). The Thailand established a Biodiesel Promotion Program in July 2001, plans to raise biodiesel production to 3.1 billion liters by 2012, accounting for 10 percent of expected diesel consumption (PECC, 2006). Investment incentives for ethanol projects and farmers assistance are provided at production level. Vehicles operating on biofuels provided 50% road tax discount and excise and fuel tax also exempted as consumption incentives.

Australia

In December 2005, the government announced a Biofuels Action Plan for achieving the target of 350 million liters of biofuel production by 2010. The excise tax paid by biofuel producers on ethanol and biodiesel is currently fully refunded to producers under a system of production grants. Under the Biofuels Capital Grants Program, A$37.6 million had been made available to encourage investment in new ethanol and biodiesel capacity. Under the Renewable Energy Development Initiative, A$100 million has been made available for new technologies, including ones applied to biofuels (PECC, 2006).

3.5 Recent History of Biofuels in Europe

In Europe, a few countries began to take an interest in biofuels during the 1990s. The EU began to pay serious attention to the subject of biofuels in 2001. A set of biofuels target were announced by an EC directive in 2003 (2003/30/EC). These include targets for all member states to replace 2% of gasoline and diesel transportation fuels by 2005 and 5.75% by 2010 on an energy basis. Despite the lack of any penalties for missing these targets, most member states have introduced support mechanism to encourage increased biofuel use. In order to boost demand for biofuels, seven EU member states have partly or completely remove fuel taxes from biofuels including Austria, Czech Republic, France, Germany, Hungary, Italy, Poland, Spain, Sweden and the United Kingdom.

A new EU directive is under way targeting 10 % biofuels in transport sector to 2020, GHG savings 35 – 45 - ? %, Car emission < 120 g CO_2/km, balanced import. To achieve the target at production level, Commission targeted to establish 500 ethanol/biodiesel plants (presently 30), 2nd generation cellulose based ethanol as sub target. At the consumption level, flexfuel ethanol/gasoline will get credit, and ethanol will made available at 30 % of refuelling stations. To balance the import, new rules/tariffs/quota will be formulated (Lindstedt, 2008).

With changes in the EU sugar regime, and with WTO ruling, the Common Market Organization in the EU recognizes small support in the sugar and the sugar beets. Simultaneously, the European Commission promotes its biofuels substantially, for environmental reasons and incidentally in order to ensure a minimal level of energy independence of EU. The States reduced their requirement for tax (the special tax in the petroleum products is basic source of income in all developed countries) when the fuel is not of mining origin, thing that renders competitive the biofuel market that usually cost double than conventional fossil fuels. This energy policy is justified with social and in the environmental criteria.

The EU sugar regime set compensation, by the EU regulation (EC) 320/ 2006. Compensation for producers and beet growers was set at amounts of €145.5M for restructuring, €43.6M for diversification and €123M for growers. In particular, it outlines that 100% of the restructuring compensation will be made available if full dismantling of production facilities occurs while 75% of compensation will be made available if the option of partial dismantling of facilities is taken (i.e., a reduction of €36.4M if some facilities are retained) (Anonymous, 2006).

In Europe most biofuel used in transport is essentially sourced from biodiesel which accounts for 79.5% of the total energy content, as opposed to 19.3% for bioethanol. The vegetable oil fuel share is becoming negligible (0.9%) and for the moment the biogas fuel share is specific to one country – Sweden (0.3%) (EuroObserv'er, 2010). After more than six years of implementation, the European directive for promotion of biofuels intended for transport has made it possible to reach biofuel consumption of approximately 12.1 million tons of oil equivalent (mtoe) in 2009 (Table 3.3). This consumption represents 4% of the energy content of all the fuels used in road transport which is a very long way short of the 5.75% goal for 2010 set in the 2003 European biofuel directive, which would require around 18 mote of biofuel use. In this situation, the European Union is going to have to increase its production and doubtless call even more on imports, at a moment when biofuels are found at the core of complex ecological and economic issues.

Though the biofuels consumption continued to increase in the European Union, but the growth of increase is at a decreasing rate. Biofuel use in transport only grew by 18.7%

between 2008 and 2009, as against 30.3% between 2007 and 2008 and 41.8% between 2006 and 2007 (EuroObserv'er, 2008, 2010).

The much more sizeable increase in biodiesel consumption (+1.7 Mtoe between 2006 and 2007) is explained not only by the wish of the member countries to meet their European obligations with respect to the directive, but also by the preferential situation of diesel fuel on the European market (61.5% of road transport consumption in 2006). Biofuel consumption benefited from the impulse linked to sizeable imports of conventional diesel fuel that makes it possible to fill the needs of the European market.

Table 3.3. Biofuels consumption for transport in European Union (in toe)

Countries	Total Consumption			
	2006[a]	2007[a]	2008[b]	2009[b]
Germany	3,475,225	4,002,748	3,139,726	2,894,407
France	737,200	1,434,215	2,274,029	2,511,490
Italy	148,967	139,350	716,419	1,167,002
Spain	168,623	373,220	613,191	1,046,528
United Kingdom	180,270	348,690	801,663	981,872
Poland	94,766	100,680	543,874	705,040
Austria	333,429	389,023	399,536	502,519
Sweden	222,473	281,251	371,407	394,231
The Netherlands	31,920	8,670	284,513	367,536
Belgium	897	91,260	99,337	258,828
Portugal	70,312	158,853	128,837	231,468
Romania	2,752	n.a	122,529	184,601
Hungary	11,990	9,180	164,722	183,791
Czech Republic	19,430	32,840	110,584	170,906
Finland	820	n.a	74,209	145,601
Ireland	3,057	8,374	55,744	73,994
Slovakia	13,160	13,262	64,799	61,861
Greece	46,440	80,840	67,398	57,442
Lithuania	19,400	52,600	61, 398	51,861
Luxembourg	538	34,963	44.011	41,154
Slovenia	4,262	13,787	21,196	29,852
Cyprus	0	n.a	14,079	15,024
Bulgaria	8,223	112,496	3,765	6,186
Latvia	2,484	1,740	1,935	4,690
Denmark	3,611	6,025	5,315	4,156
Malta	835	0	661	583
Estonia	633	n.a	4,236	n.a.
Total EU 27	**6,601,718**	**7,694,097**	**10,189,113**	**12,092,625**

Source: [a]Biofuels Barometer, le journal des energies renouvelables, EurObserv'er, June 2008.
[b]Biofuels Barometer, le journal des energies renouvelables, EurObserv'er, July 2010.

The less significant increase in bioethanol consumption (+ 0.36 Mtoe) is explained not only by a lower market share for petrol in Europe (36.9% of road transport consumption in 2006), but also by the very strong increase in the price of cereals. In spite of this unfavourable context, European consumption of fuel bioethanol has been able to continue its rise and this for several reasons. Since part of the purchases of cereals were formalized by contract with farmers before this strong increase in prices, the production of bioethanol from sugar beets was affected less, and bioethanol imports coming principally from Brazil have strongly increased. Brazil's bioethanol, produced from sugar cane, is principally consumed in Sweden, the UK and the Netherlands. It is consumed in smaller quantities in Denmark and Germany.

3.6 Biofuels Activity in Greece

Greece has a biofuel target provided by the European Commission of 5.75 percent of total fuel consumption by 2010. The Government of Greece (GOG) is aiming to produce 160 million liters (ML) of biodiesel and 400 ML of bioethanol annually by 2010 (Sekliziotis, 2007). According to EU Directive 2003/30, Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 31 December 2004 at the latest (EU, 2003). In 23 January, 2008, the commission proposed for a Directive aims to establish an overall binding target of a 20% share of renewable energy sources in energy consumption and a 10% binding minimum target for biofuels in transport to be achieved by each Member State, as well as binding national targets by 2020 in line with the overall EU target of 20% (EC, 2008). Greece has undertaken a programme for obligatory use of biofuels (Law 3423/2005). Greece passed the Law 3653/2008 with Article 55: Biodiesel, new methodology for sharing the annual dispensable quality with Criteria: energy crops, used vegetable oil, consistency, capacity, R&D, ISO and Article 56: Bioethanol, provision for obligatory absorption during the period 2010-2016 (Georgakopoulou, 2008).

At present there are four plants in Greece already producing biodiesel, with another six to enter into production within the next three years. These facilities are supported with funds from the EU and the GOG. The largest of them is scheduled to enter production in 2008 with an estimated total investment of € 10 million and an annual capacity of 50 ML of biodiesel. The GOG has provided tax incentives for the production of biodiesel, and is allocating the untaxed output to thirteen different distribution companies. In calendar year 2005 only 3 MLs of biodiesel were produced, and in 2006 some 73 MLs, of which 41 MLs were distributed. In calendar year 2007, 114 ML allowed distribution with tax breaks; part of this will come from year 2006 carry-over stocks, and the rest from 2007 production.

The Government of Greece has decided to ask the European Commission for permission to convert two of Greece's five existing sugar plants into bioethanol production facilities. If approved, Greece would dedicate some 50 percent of its current EU quota for sugar beet to meet the demand created by these two plants. The objective is to support the Hellenic Sugar Industry and sugar beet producers by giving them the option to continue cultivation of the crop. At full production these two plants would have a total output of 120 MLs of bioethanol (Table 3.4). Some 80,000 metric tons of sugar beets will be needed, along with 53,000 metric tons of molasses (also from beets), and 265,000 metric tons of cereals (Sekliziotis, 2007).

Table 3.4 Greek Biofuel Production - Actual and Estimated

Location	Installed Capacity (Million liters)	Start Production	Type of Fuel
Kilkis, Central Macedonia	40	2005	Biodiesel
Kozani, Western Macedonia	50	2008	Biodiesel
Patras, W. Peloponnese	60	2006	Biodiesel
Ahladi, Phtiotis, Central Greece	280	2006	Biodiesel
Volos, Thessaly, Central Greece	40	2006	Biodiesel
Thessaloniki, Macedonia	43	2005	Biodiesel
Four Small Plants Planned	50		Biodiesel
Total Biodiesel Capacity	**563**	**2008**	
Larisa, Thessaly, Central Greece	60	2009	Bioethanol
Xanthi, Thrace	60	2009	Bioethanol
Other forecast investments	270	2010	Bioethanol
Total Bioethanol Capacity	**390**	**2010**	

Source: Biofuel Activity in Greece, Global Agriculture Information Network (GAIN) Report, USDA Foreign Agricultural Service, February 2, 2007.

3.7 Technical Options for Sugar Industry in Greece

With changes in the EU sugar regime, and with WTO ruling, the Common Market Organization in the EU has excluded sugar and sugar beet for non-food use (sugar for the chemical and pharmaceutical industries and for energy purposes) from production quota restriction. Simultaneously, the European Commission substantially promotes bio-fuels for environmental reasons and in order to ensure a minimal level of energy independence of EU. The States reduced their requirement for tax (the special tax in the petroleum products is basic source of income in all developed countries) when the fuel is from non-fossil origin, which renders competitive bio-fuels that usually cost twice as conventional fossil fuels. The EU sugar regime set compensation, by the EU regulation (EC) 320/ 2006 both for growers and industries. Compensation for producers and beet growers was set at amounts of €145.5M for restructuring, €43.6M for diversification and €123M for growers. In particular, it outlines that 100% of the restructuring compensation will be made available if full dismantling of production facilities occurs, while 75% of compensation will be made available if the option of partial dismantling of facilities is taken (i.e., a reduction of €36.4M if some facilities are retained) (Anonymous, 2006). So, both the partial and complete transformation of production facility for bio-ethanol in the sugar industry is supported by the regulation and according to the requirement and commodity price, i.e. price ratio of sugar to ethanol, one can choose an optimal ratio between sugar and ethanol production.

Under the new CAP, the Greek sugar quota has reduced by 50.2 percent and the Hellenic Sugar Industry (HSI) has benefited by the amount of €118 million from the EU. In order for the HSI to accept the reduction of the quota by 50.2 percent, the EU has offered financial support to the Greek Industry to be spent for restructuring and investment. For Greece, the initial amount decided and agreed was at €118 million, of which to date 87 million have already been paid to HSI and the remaining 31 million will not be paid unless H.S.Co. finally implements its bio-ethanol program (Sekliziotis, 2009).

The option of the HSCo. to convert altogether two sugar plants to ethanol production was announced in 2006, however despite consecutive calls to investors the process is still open and the sugar factories ceased operation without starting ethanol production.

CHAPTER IV: GHG EMISSION IN BIOFUEL PRODUCTION SYSTEM

4.1 Introduction

Use of biofuel in the internal combustion engine is undoubtedly less pollutant than fossil fuel but considering life cycle GHG emission may controversial because bio-energy production still often relies on the use of fossil energy sources, e.g. coal, oil, natural gas, the resulting net energy saving benefit depends on how large the extent of the reliance is. Biomass from plants emits, when transformed into energy as much as carbon dioxide as the one captured during the photosynthetic process of the plant growth[9] plus emission due to energy consumed during the cultivation, collection and delivery (agriculture) stage and the transformation (industry) stage of biofuel production. The overall net contribution to the reduction of anthropogenic greenhouse gas emissions made decision makers to pay particular attention and to support in some cases biofuel production. Especially when positive synergies with other public policy goals have been observed, governments have proceeded to support biofuels by applying tax exemptions so that the biofuels become competitive in the energy market. The above policy was coordinated to the CAP reform of 1992 that initiated the decoupling of aides to farmers from productivist practices, and biofuel activity gained momentum thank to a pivot element of the reform, namely the obligatory set aside measure not applied to energy and in general industrial crops.

Seventeen years after the take-off of the tax exemption program, bio-fuels are still more costly than fossil fuels and the agro-energy industrial activity largely depends on government subsidies for its viability. On the other hand, environmental problems have become more acute and international commitments mean that the abatement of Greenhouse Gas (GHG) emissions requires intensified efforts. Given the fact that biofuel substitution for fossil fuels reduces GHG emissions, the question arises as to whether subsidies for bio-fuels can be justified on the grounds that they contribute to a reduction in the greenhouse effect. Even if

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[9] Many authors treat CO_2 emission from ethanol combustion are zero or neutral because these emissions comes from the atmosphere through photosynthesis process for biomass growth (Wang, M.Q., 1996. Greet 1.0- Transportation fuel cycle model: Methodology and use. In: U.S. Department of Energy, C.f.T.R., Energy Systems Division, Argonne National Laboratory (Ed.), Argonne, Illinois., Malça, J., Rozakis, S., Freire, F., 2005. Bioethanol replacing gasoline: greenhouse gas emissions reduction, life-cycle energy savings and economic aspects. 2nd International Conference on Life ycle Management, Barcelona, pp. 510-514. Cadenas, A., Cabezudo, 1998. Biofuels as Sustainable Technologies: Perspectives for Less Developed Countries. Technological Forecasting and Social Change 58, 83-103.;DEFRA, 2010. Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. In: Department for Environment, F.a.R.A. (Ed.). Government of UK. For the same reason, combustion of biomass that certainly produces CO_2 emission is also treated as zero.

the recent rise in crude oil prices alleviates the budgetary burden that bio-fuels represent, the question raised by economists concerning the efficient allocation of this amount among bio-fuel chains through tax exemptions to the bio-fuel processors is of primary importance.

4.2 Estimation of GHG emission in ethanol production system

Due to use of fossil energy in the production system, GHG emission for ethanol production takes place during biomass cultivation, transportation of biomass to ethanol plant and in the transformation stages. CO_2 emission during ethanol combustion is treated as zero as because the same amount of CO_2 absorbed during the photosynthetic process of the biomass growth. Thus, the net emission depends on the fossil input use in feedstock production, distance from farm to ethanol plants, and efficiency of ethanol production from different feedstock in industrial processing.

Fossil energy used involved in farm production are calculated on the basis of amount of fuel and fertilizer used in the production process. So, by inputting the amount of fuel used, amount of fertilizer used and the amount of energy used to produce fertilizer, we can calculate the energy input for the production of agricultural biomass. On the other hand, energy used in the industrial processing is calculated on the basis of basic energy used. For example, steam power is used for industrial processing and steam is generated by fuel oil. Thus, amount of fuel oil used for steam generation is considered for steam energy.

Life cycle emission factor is used to calculate CO_2 emission from respective fossil energy used. These conversion factors are enabling to convert activity data into kilograms of carbon dioxide equivalent (CO_2e). Carbon dioxide equivalent is a universal unit of measurement used to indicate the global warming potential of one unit of carbon dioxide. It is used to evaluate the releasing of different greenhouse gases (Malça, 2002), nitrous oxide (N_2O) etc. against a common basis (DEFRA, 2010). The emission factors used in this study incorporated emissions from the full life-cycle of the energy and included net CO_2, CH_4 and N_2O emissions. Lifecycle emissions include both direct emissions from combustion and indirect emissions associated with the production and transportation of the fuel (DEFRA, 2010).

4.2.1 Calculation of CO_2 emission factors

CO_2 emission factors express the amount of CO_2 in kilograms which is emitted by combusting a certain type of fuel. Life cycle emission factor for a certain fuel consider both direct emission from combustion and indirect emission prior to combustion emitted for extraction, collection, refinement transportation to the consumer of the fuel (DEFRA, 2010). Emission factors can also be based on the energy content, i.e. joules. The following points are fundamental to the procedure used to calculate CO_2 emission factor.

(a) the end energy of all sub-processes is considered for calculation.
(b) the particular end energies are converted into primary energy by including pre-chain losses; and
(c) the emission factor is expressed on the basis of primary energy such as coal or crude oil and not of end energies such as electricity.

4.2.1.1 Estimation of CO_2 emission factor for diesel

The process steps of the diesel fuel chain are:

(a) exploration, extraction, preparation and transportation of crude oil to the refinery;
(b) diesel fuel production in the refinery;
(c) transportation of the diesel fuel to the consumer;
(d) losses due to evaporation and during transfer processes; and
(e) combustion of diesel fuel.

At a density of 0.835 kg/l of diesel fuel and a lower heating value (LHV) of 42.7 MJ/kg (respectively, 37 MJ/l) of diesel fuel, total CO_2 emissions (direct and indirect) are 3.45 kg CO_2/kg (respectively, 2.88 kg CO_2/l) diesel fuel (Lewandowski et al., 1995) (Table 4.1).

Table 4.1. Emission factors expressed in kg CO_2/kg diesel fuel

Indirect emissions	
Exploration and transportation of crude oil to the refinery	0.06
Refinery conversion	0.16-0.26
Transportation to consumer	0.02
Evaporation	<0.005
Sum indirect emissions	0.25-0.35
Direct emissions	3.15
Total emissions	3.4-3.49

4.2.1.2 Estimation of CO_2 emission factor for hard coal

Approximately 4.5% of its energy content is needed for the exploration, mining and transportation of hard coal. The LHV of hard coal is 29.3 MJ/kg; 1.32 MJ are needed to obtain 1 kg hard coal. This energy is provided mainly by diesel fuel. For 1 kg hard coal, 0.0309 kg diesel fuel with an energy content of 42.7 MJ/kg is needed. The amount of diesel fuel consumed is multiplied by its CO_2-emission factor. The result shows that, 0.0309 kg diesel fuel/kg hard coal x 3.45 kg CO_2/kg diesel fuel = 0.1 kg CO_2 are emitted for the provision of 1 kg hard coal. Direct CO_2emissions during the combustion of hard coal are 93.2 kg CO_2/GJ or 2.73 kg CO_2/ kg hard coal. Thus the CO_2 emission factor for hard coal is 2.83 kg CO_2/kg hard coal (direct and indirect).

4.2.1.3 CO_2 emission factor for electrical energy

The CO_2 emission factor for electrical energy is calculated 0.618 kg CO_2/kWh (Table 4.2). This figure is calculated on the basis of the provisional chain for the primary energy which is consumed during the production of electricity, as well as power station losses during electricity production.

4.2.1.4 CO_2 emission factor for natural gas and gasoline

Life cycle emission factor for natural gas is 3.116 kg CO_2/kg natural gas on the other hand life cycle emission factor for gasoline is estimated 3.152 kg CO_2/kg gasoline (DEFRA, 2010) (Table 4.2). (DEFRA, 2010) calculated those emission factors considering both direct emission at use stage and indirect emission emitted prior to the use.

Table 4.2. Energy content and CO_2 emission factors for different kinds of energy or fuel

Kind of fuel or energy	(MJ/kg, MJ/kWh)	CO_2 emission factor
Diesel fuel, fuel oil	42.7 MJ/kg	3.45 kg CO_2/kg[a]
Hard coal	29.3 MJ/kg	2.83 kg CO_2/kg[a]
Electricity	3.6 MJ/kWh	0.618 kg CO_2/kWh[a]
Natural gas		3.116 kg CO_2/kg[b]
Gasoline	43.5MJ/Kg	3.152 kg CO_2/kg[b]

[a] (Lewandowski et al., 1995)

[b] (DEFRA, 2010)

4.2.2 GHG emission in agricultural production

Biomass production required plowing, sowing/transplantation, fertilization, irrigation, harvesting etc. Fossil energy like diesel is required for machinery operation, natural gas, coal, oil is required for fertilizer production. To estimate GHG emission in biomass production, all operational activities and input/material used have been taken into consideration.

Main source of emission in the farming is the fuel and fertilizer used in the production process. In the present study, GHG emission in the agriculture sector is calculated on the basis fossil energy used for each crop per ha. CO_2 emission for machinery operation is calculated by the amount of fuel (diesel) used multiplied by emission factor. Fossil input requirement for each crop is presented in Appendix III. To calculate emission from fertilizer, the amount of fossil energy used to produce fertilizer is taken into consideration. Natural gas, coal and oil is used for the production of different fertilizer. Fossil energy requirement for fertilizer and their associated CO_2 emission is presented in Table 4.3. Detailed CO_2 emission for cultivation of 1 ha irrigated wheat is presented in Table 4.4. GHG emission in crop cultivation and transportation for all crops are presented in Appendix IV. To Calculate CO_2eq emission for imported wheat and maize from Eastern Europe, BioGrace Model for GHG calculation is used (Appendix V).

Table 4.3. Fossil energy requirement and CO_2 emission per kg fertilizer

Fossil energy for fertilizer production	N	P_2O_5	K_2O
Nat gas	2.951 (0.947)	0.704 (0.226)	0.446 (0.143)
Oil	0.188 (0.0546)	0.649 (0.188)	0.115 (0.0334)
Coal	0.072 (0.0254)	0.087 (0.0306)	0.089 (0.0316)
Total emission	**3.211**	**1.44**	**0.65**

Parenthesis represent amount of input to produce one kg of respective fertilizer (Malça, 2002).

Table 4.4 CO_2 emission for cultivation of 1 ha irrigated wheat.

Operation/input	Required fossil energy	CO_2 emission
Machinery operation like plowing, sowing/ transplanting, fertilization, irrigation, harvesting, etc.	Diesel: 54.57 litre	54.57×3.45[a]=188.27 kg
Fertilizer		
Nitrogen- 123.75 kg	Natural gas:123.75×0.947[b] =117.69kg	117.19×3.116[a]=365.17 kg
	Oil: 123.75×0.0546[b] = 6.75 kg	6.76×3.45[a] = 23.31 kg
	Coil: 123.75×0.0254[b] = 3.14 kg	3.09×2.83[a] = 8.9 kg
	Total CO_2 for Nitrogen	397.38 kg
P_2O_5-20 kg	Natural gas: 20×0.226[b] = 4.52kg	4.52×3.116[a] =14.08 kg
	Oil: 20×0.188[b] = 3.76 kg	3.76×3.45[a] = 12.97 kg
	Coil: 20×0.0306[b] = 0.61kg	0.61×2.83[a] = 1.73 kg
	Total CO_2 for P_2O_5	28.78 kg
Total CO_2 emission in wheat production (per ha)		614.42 kg

[a] Emission factor from Table 4.2.

[b] required amount (kg) of input to produce 1 kg respective fertilizer from Table 4.3.

Calculation of GHG emission for fertilizer for different crops can be presented with the following matrix notation.

$$GHGq = (3.116 \quad 3.45 \quad 2.83) \,.\, \begin{bmatrix} 0.947 & 0.226 & 0.143 \\ 0.0546 & 0.188 & 0.0334 \\ 0.0254 & 0.0306 & 0.0316 \end{bmatrix} . \begin{bmatrix} 123.8 & 206 \\ 20 & 80 \\ 0 & 60 \end{bmatrix}$$

GHGquant(crop) = unitGHGemiss(energy type) energyContent(energy type, element) input(element, crop)

The row vector contains emission factors i.e., kg CO_2 emission per kg fossil energy (natural gas, oil, coal, respectively), 3×3 matrix contains required amount (kg) of fossil energy (natural gas, oil, coal, respectively) for the production of 1 kg respective fertilizer in rows and different fertilizer (N, P_2O_5, K_2O, respectively) in column. The last matrix (3×2) represents requirement of fertilizer (N, P_2O_5, K_2O, respectively) per ha in rows and crops in column. For convenience, two crops, wheat and cotton, respectively are presented here.

We do the same kind of calculations for all crops present in the crop mix of the region under study (Table 4.6 prepared from Table 4.3, Appendix IV, and Table 4.5). The final CO_2 emissions caused by ethanol production at the agricultural stage are the differential between the crop used for biomass (i.e. wheat) and those crops replaced by wheat. For instance, let's suppose that irrigated wheat is designated to be transformed in bioethanol, cultivated in soil previously cropped by cotton. For each ton of ethanol, 3.344 tons of wheat are required (in other words 3.344 / 7 ha are required to produce 1 t of ethanol), then CO_2 emissions caused by the biomass input to biomass should be (3.344/7)×(614.42 - 1502.15) = - 424.08 kg CO_2 / t ethanol. This is the substitution method that is better implemented when a model is available to estimate all substitutions at the area level, that usually are not obvious at a simple glance.

4.2.2.1 N_2O emission

N_2O emission from fossil energy used for machinery operation, fertiliser manufacture, etc. and nitrous oxide from the manufacture of nitrogenous fertiliser, is included in the life cycle carbon dioxide equivalent (CO_2e) emission from respective fossil energy used. The present section is devoted to estimate N_2O emission from soil due to use of nitrogenous fertilizer for different crops. Indirect N_2O emission from additions of nitrogenous fertilizer to land due to deposition and leaching is also estimated. (Börjesson, 2009) mentioned that, often emissions of nitrous oxide contribute more than emissions of carbon dioxide, but may vary widely depending on local conditions. N_2O a by-product of fixed by the nitrogen application in agriculture with a 100 year average global worming potential (GWP) is 296 times larger than an equal mass of CO_2. Here, emissions of nitrous oxide from land are estimated from the latest IPCC model (IPCC, 2006). N_2O emission for the cultivation of one ha land is appeared ranges from less than 1 kg per ha to about 4 kg per ha. Highest emission per ha is found in maize production and the lowest is in alfalfa cultivation (Table 4.5).

Table 4.5 N_2O emission for cultivation of 1 ha crops in the area

Sources of N_2O emission	N_2O emission per ha cultivation (Kg/ha)										
	sfw	drw	wir	mze	tob	cot	pot	sbt	tom	mzf	alf
Direct N_2O emissions	1.238	1.238	1.238	3.340	1.800	2.060	1.645	1.100	1.800	3.340	0.553
Indirect N_2O emissions	0.124	0.124	0.124	0.334	0.18	0.206	0.165	0.11	0.18	0.334	0.055
Total N_2O emission	**1.361**	**1.361**	**1.361**	**3.674**	**1.98**	**2.266**	**1.810**	**1.21**	**1.98**	**3.674**	**0.608**
Kg CO_2 equivalent	**402.9**	**402.9**	**402.9**	**1087**	**586.1**	**670.7**	**535.6**	**358.2**	**586.1**	**1087**	**180**

Elaboration of Notation: **sfw**: soft wheat, **drw**: durum wheat, **wir**: irrigated wheat, **mze**: maize, **tob**: tobacco, **cot**: cotton, **pot**: potato, **sbt**: sugar beet, **tom**: tomato, **mzf**: maize for fodder, **alf**: alfalfa

Table 4.6 CO_2 emission for cultivation of 1 ha crops in the area

Sources of CO_2 emission	CO_2 emission per ha cultivation (Kg/ha)										
	sft	drw	wir	mze	tob	cot	pot	sbt	tom	mzf	alf
Nitrogen	397.4	397.4	397.4	1072.5	578	661.5	528.2	353.2	578	1073.5	177.5
P_2O_5	28.8	28.8	28.8	143.9	115.2	115.2	128.1	57.6	115.2	143.9	259.1
K_2O	0	0	0	0	65	39	113.8	65	65	0	0
Diesel	167.6	167.6	188.3	551.4	815.2	686.5	929.1	393.5	929.1	551.4	280.4
subtotal	**593.7**	**593.7**	**614.4**	**1767.9**	**1573.4**	**1502.1**	**1699.2**	**869.3**	**1687**	**1767.9**	**717**
From N_2O	**402.9**	**402.9**	**402.9**	**1087**	**586.1**	**670.7**	**535.6**	**358.2**	**586.1**	**1087**	**180**
Total emissions agriculture	**996.6**	**996.6**	**1017**	**2855**	**2160**	**2173**	**2235**	**1228**	**2273**	**2855**	**897**

Usually in research work impacts on carbon dioxide emissions from the introduction of energy crops are studied statically and most of the times focus on changes due to conversion of different land uses. During the 1990's energy crops were allowed to cultivate in obligatory set aside land, thus in several studies the reference system is fallow land.

For instance a study on environmental impact of taking fallow land into use by cultivating Miscathus in Germany is calculated by (Lewandowski et al., 1995). Furthermore, a recent study estimating GHG costs of energy crop production in the UK (St. Clair et al., 2008) focuses mainly on conversion of broadleaved forest or grassland to Short Rotation Coppice or rape seed. Concerning arable land they mention that rapeseed "(OSR) production has similar GHG costs to arable cropping". Nevertheless when they compare GHG emissions of rapeseed for biodiesel against wheat a concrete even small difference is observed that is multiplied by three in the case of wheat under reduced tillage practice. A similar approach is adopted to assess ethanol GHG benefits where the author compare ethanol produced in Sweden against that produced in Brazil or the US. He concludes that there is good and bad ethanol (Börjesson, 2009). It is stated that grain to ethanol results in no change of CO_2 emissions if it is cultivated on "normal" arable land.

Certainly GHG differentials when converting from grassland to intensive energy cropping are spectacular at the expense of energy crops, however even displacements and replacements among arable crops reveal significant differences in GHG costs or gains. As a matter of fact, in the arable system of Thessaly as the Table 4.7 below (that is derived from Table 4.6) shows, GHG differentials for every crop change in pairs. CO_2 emission impacts ranges about from -2000 to +2000 kg/ha (when substitute alfalfa for maize and vice versa). In a mathematical programming context when the marginal land use for energy cropping is determined as the optimal solution of parametric regional farm (income maximization under constraints) model we apply unitary coefficients in Table 4.7 in order to calculate post optimal GHG costs or gains of the introduction of energy crops in the crop mix. The aggregate GHG results is converted in an ethanol ton basis in order to calculate the total GHG emissions for bioethanol production and compare them with the alternative gasoline emissions.

It should be noted at this point, that differentials in crop mix without and with the cultivation of the energy crop may be influenced by policy parameters. Especially in Europe changes in the Common Agricultural Policy alter the 'reference system' upon which the GHG emissions of the biomass to energy are measured. One can mention a study to estimate supply curves of solid biomass to electricity that points out differences between these curves after the latest 2003 major CAP reform (Lychnaras and Rozakis, 2006).

Table 4.7. The GHG savings in kg CO_2 equivalent / ha when converting from one crop to the other

GHG changes when converting crop in line to that in column

	sfw	drw	Wir	mze	tob	cot	pot	sbt	tom	mzf	alf
sfw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
drw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
wir	-21	-21	0	1838	1142	1156	1217	210	1256	1838	-120
mze	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
tob	-1163	-1163	-1142	696	0	13	75	-932	114	696	-1263
cot	-1176	-1176	-1156	683	-13	0	62	-945	100	683	-1276
pot	-1238	-1238	-1217	621	-75	-62	0	-1007	39	621	-1338
sbt	-231	-231	-210	1628	932	945	1007	0	1046	1628	-331
tom	-1277	-1277	-1256	582	-114	-100	-39	-1046	0	582	-1376
mzf	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
alf	100	100	120	1958	1263	1276	1338	331	1376	1958	0

4.2.3 CO_2 emission in transportation

CO_2 emission for transportation is estimated on the basis of diesel used for transportation. Twenty five kilometer distance in average is assumed. Diesel requirement for transportation is considered 0.0223 kg diesel per km for 1 ton feedstock (Malça, 2002). Life cycle CO_2

emission factor for diesel (3.45 kg CO_2 per kg diesel) is used to calculate CO_2 emission in transportation. Hence, CO_2 emission for transportation of 1 ton feedstock is: 0.0223×25×3.45 = 1.92 kg. In case of wheat, 3.344 ton of grain is required to produce 1 ton of ethanol. Consequently, CO_2 emission for transportation of wheat feedstock for one ton ethanol is: 1.92×3.344 = 6.42 kg.

4.2.4 CO_2 emission in the industrial process

CO_2 emission during the industrial processing is largely depended on what fuel is used to produced the heat, steam and electricity required for manufacture of bioethanol. In the present study, electricity and steam is used in the industrial processing. Steam is produced by using fuel oil. To produce one ton of steam, 0.072 ton of fuel oil is required (LIBEM model, for details see in the Appendix V). In case of ethanol production from wheat, 5 tons of steam is required for the production of one ton ethanol. Energy input for the transformation process assumed to be the highest part in bioethanol production system. Hence, bio-energy based industrial processing system can drastically improve GHG balance (Koga, 2008).

Steam and electricity requirement and CO_2 emission for industrial processing for 1 ton ethanol production from wheat is shown in Table 4.8. Net CO_2 emission for the production of 1 ton ethanol from wheat, instead cotton cultivation is presented in Table 4.9.

Table 4.8. CO_2 emission in the industry for the production of 1 ton ethanol from wheat

Operation/input	Required fossil energy	CO_2 emission
Steam- 5 ton	Fuel oil: 5×0.072 = 0.36 ton	0.36×3450 = 1242 kg
Electricity	503 kWh	503×0.618 = 310.85 kg
Total CO2 emission		**1552.85 kg**

Table 4.9. Net CO_2 emission for the production of ethanol from wheat

Source of emission	CO_2 emission (kg/kg ethanol)
Agriculture	- 0.42408
Transportation	0.00642
Industrial processing	1.55285
TOTAL net	**1.135**

4.3 Comparison of CO_2 emission in ethanol production in different studies

CO_2 emission in bioethanol production is varied in different studies. Differences in feedstock, different agro climatic condition in different places, soil condition influences use of inputs and energy in feedstock production. On the other hand, fuel and energy used in the industrial for ethanol production plays big role in total CO_2 emission in ethanol production. Use different methods and parameters to calculate the emission is also contribute significant differences in CO_2 estimation. For example, (Börjesson, 2009) showed that, keeping agricultural practice similar for biomass production, emissions from industrial processing in ethanol production account for less than 10% of total emissions when biomass is used as fuel in ethanol plants for producing ethanol from wheat. When natural gas and coal are used, this amount increases to approximately 40% and just below 60%, respectively (Table 4.10). (Börjesson, 2009) also find that land type and land use change has significant influence on CO_2 emission.

(Murphy and McCarthy, 2005) conducted a study on ethanol production sugar beet and waste like paper and newspaper. They calculated ethanol production performance/rate, CO_2 emission in production and combustion on the basis of chemical and molecular properties of different feedstock, fuel and energy used and ethanol combustion. They found that CO_2 emission in the industrial processing accounted for more than 90% where agricultural biomass accounts for only 9% (Table 4.10).

In our present study, more than 80% of CO_2 emission accounted for industrial processing where steam and heat are produced to be considered by fuel oil and electricity. CO_2 emission in ethanol plant per ton of ethanol is estimated 1553 kg/ t of ethanol which is very close (1549 kg/ t ethanol) to (Börjesson, 2009) when coal is used as energy source for ethanol plant (Table 4.9). We found CO_2 emission for wheat feedstock production is 614.42 kg CO_2 /ha which is accounted for 294 kg CO_2/t ethanol. For sugar beet feedstock, we found 869 kg CO_2 /ha is emitted for beet production which is accounted for 194 kg CO_2/t ethanol. (Murphy and McCarthy, 2005) found 1600 kg CO_2/ha is emitted for sugar beet cultivation that is accounted for 368 kg CO_2/t ethanol. CO_2 emission in feedstock production estimated by (Börjesson, 2009) is much higher (1202 kg CO_2/t ethanol and 7500 kg CO_2/ha) perhaps may be different amount of fuel and energy and technology used (Table 4.9). (Börjesson, 2009) used different rate of transformation of grain to ethanol. He considered 2.3 ton grain for 1 litre ethanol, i.e., 2.9 kg grain for 1 kg ethanol production where as we considered 3.344 kg grain for 1 kg ethanol production.

Table 4.10 Comparison of CO_2 Emission per ton (and per ha of wheat) of ethanol production

Sector of CO_2 emission	Kg CO_2/ t ethanol		
	This study	Borjesson, 2009	Murphy & McCarthy (sugar beet)
Industry	1552.85 (84%)		3675.53 (91%)
Steam(fuel oil)	1242		
Electricity	310.85		
ether, Forest chips		82.77 (total) (6.44%)	
or, Natural gas		827.7 (total)(40.79%)	
or, Coal		1548.6 (total) (56.31%)	
Agriculture (Per ton)	293.52 (16%) (614.42/7)×3.344	1201.5 (45kg/GJ eth×26.7GJ(=1t))	367.55 (9%)
Per ha	614.42 Kg CO_2/ha	7500.212 Kg CO_2/ha (7.5/2.915)×1201.5	1600kg CO_2/ha

4.4 GHG saving and cost of CO_2 saving

There are two sectors from where CO_2 emission could be saved. At the first, introduction of energy crop in the farming could reduce emission, provided that energy crop like wheat is less exhaustive compare to some other arable crops. Change in crop mix i.e., indirect land use change (iLUC) could also change GHG emission. Secondly, use of bioethanol that has very limited emission, replaces highly emission gasoline use resulting net emission is reduced.

To estimate GHG saving, life cycle GHG emissions of gasoline are considered as reference for comparison with ethanol. Hence, it is necessary to derive the fuel equivalency ratio between ethanol and gasoline. In terms of fuel efficiency, gasoline is found more fuel efficient but efficiency varies significantly on the types of vehicle engine. (Warnock et al., 2005) mentioned that fuel efficiency of automobiles is reduced by 27 percent on E-85 compare to pure gasoline. On the other hand (Sheehan et al., 2004) conducted a study with flexible fuel vehicle (FFV) to estimate the efficiency of the engine running on E85 and gasoline and found that the difference between the efficiency of the engine running on these two fuels is negligible. (Yacobucci, 2005) mentioned that fuel economy of ethanol is reduced by approximately 29%. PTT Research and Technology Institute, Thailand has conducted tests for various car models running on conventional gasoline and gasohol E10 (Toyota 1.3 L/1993, Toyota 1.5 L/1996, Toyota 1.6 L/2000, Nissan 2.0 L/1994, Mitsubishi 1.5 L/1994, Volvo 2.3 L/1995, Honda 1.6 L/1996). The fuel economy test results show a difference between gasoline and gasohol in the range of -1.1% to +1.7% in different models (Nguyen et al., 2007). (Macedo et al., 2008) derived and adopted an equivalence of 1 L ethanol (anhydrous) to 0.8 L gasoline. Substitution ratio between ethanol and gasoline is 0.8 has also suggested by (Nguyen et al., 2009). Considering all types of vehicle and findings of other writers, fuel efficiency of ethanol is considered 80% of gasoline.

Cost of CO_2 saving i.e., the deadweight loss that the society has to pay for CO_2 saving is the amount of subsidy needed to support the ethanol production cost so that the agents can gain breakeven cost. Import price of gasoline (unleaded premium 10ppm fob) is used as reference cost. This is the optimum amount of tax credit requirement that is deadweight loss for the society for biofuel to be competitive with fossil fuel. Fuel efficiency factor is used to calculate cost equivalency. To estimate the cost of CO_2 emissions saving, net saving is calculated. Net CO_2 savings is the savings from the agriculture due to change in farming practice after introduction of energy crops and the amount of saving due to replacement of fossil fuel by bioethanol deduced by the net emission caused for transportation and industrial processing.

CHAPTER V: METHODOLOGY FOR ECONOMIC AND ENVIRONMENTAL EVALUATION OF BIO-ETHANOL

5.1 Introduction

This chapter describes the methodology which is adapted in this study to be used as a decision-support tool in the optimization of bio-energy systems. Cope with new CAP and Greek sugar industry perspective, a sector mathematical programming is used to evaluate the conversion of a sugar factory to an ethanol production plant. Partial equilibrium agricultural sector modelling and engineering approaches, applied to the industrial model, are jointly exploited to determine the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply. The most efficient farmers will provide beet and grain at the lowest possible prices. At the same time environmental impact of bio-fuel production is assessed under life cycle assessment (LCA) framework.

The integrated methodology has been designated by *Life Cycle Activity Analysis* (LCAA), being based on the integration of Activity Analysis - a well-known procedure in economics - with the environmental Life Cycle Assessment methodology, which aims to quantify the environmental impacts of a product from ‘cradle’ to ‘grave’. According to (Varela et al., 2006), five generic process steps – from the production of biomass, transportation of biomass, the conversion into bioethanol, distribution of bioethanol until the supply of a transportation service, and vehicle using bioethanol have been considered to aggregate the economic and environmental performance for the whole life cycle of boiethanol (Figure 5.1).

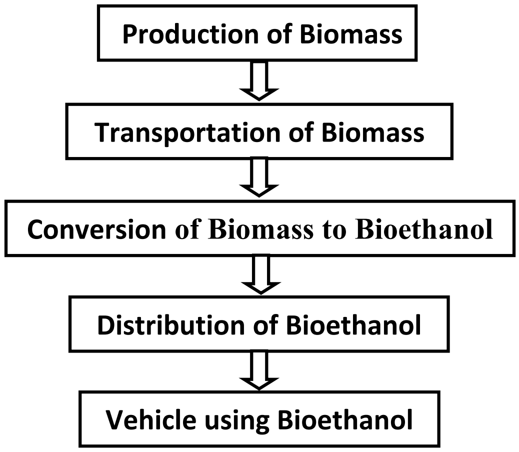

Figure 5.1 Five generic process steps for life cycle of biethanol

5.2 Mathematical Programming Model

Models are idealized representation of the essential aspects of an existing system. In economics, a model is a theoretical construct that represents economic processes by a set of variables and a set of logical and quantitative relationships between them (Hillier and Lieberman, 1995). Mathematical models are also idealized representation, but they are expressed in terms of mathematical symbols and expressions.

Mathematical programming is perhaps the most developed and more often used technique of decision-making in economics. Its objective is the optimum distribution of limited resources among competitive activities under certainty conditions. A mathematical programming model is constituted by a function that expresses the objective that we want to maximize or to minimize (objective function) and a set of other linear functions that constitutes the restriction of each problem. These restrictions have make with capacity, availability of resources, technology etc.

The general characteristics of mathematical programming are the objective function and the restrictions they constitute mathematical interrelations. Depending on the conditions of each problem to resolution, it followed different technique of mathematical programming. There are four types of mathematical programming:

- Linear programming, it constitutes the most known type of mathematical programming and it presupposes that all interrelations are linear.
- Non linear programming, where certain of the interrelations are not linear.
- Integer programming, where the variables of problem take only entire prices represent decisions “reasonable” and no natural sizes.
- Dynamic programming, when the problem develops diachronically even under conditions of uncertainty.

Linear programming is a powerful technique for dealing with the problem of allocating limited resources among competing activities as well as other problems having a similar mathematical formulation. More precisely, this problem involves selecting the level of certain activities that compete for scarce resources that are necessary to perform those activities. The choice of activity levels then dictates how much of each resource will be consumed by each activity. It seeks the best possible (i.e., optimal) solution of the problem.

In the context of environmental problems, a number of tools for environmental analysis have been developed in the past decades to study the flows of substances, materials and products through the economic system and to assess the associated environmental impacts. Well-known examples of these tools are life cycle assessment (LCA), material flows analysis (MFA), substance flow analysis (SFA), environmental impact assessment (EIA), risk assessment (RA), etc. The purpose of LCA is to study the environmental impacts of a product or a service from the "cradle" to the "grave"[10]. MFA is used to analyze the materials throughput or the materials intensity of important sectors or large functional systems of the national economy, and therefore concentrates on bulk mass flows. SFA is used to identify the causes of specific environmental problems in the economy and find possibilities for amending or preventing those problems, etc. Many of these tools have different purposes and different systems as their objects, however, in general, they include neither the description of costs nor the mechanisms of economic analysis (Bouman et al., 1999).

This study attempts to evaluate economic and environmental performance of biofuel production potentialities in the sugar industry in Greece. Cope with new CAP and Greek sugar industry perspective, a sector mathematical programming is used to evaluate the conversion of a sugar factory to an ethanol production plant and at the same time environmental impact of bio-fuel production is assessed under life cycle assessment (LCA) framework. The possible techniques of production activities available to a sector i.e., activity analysis (AA) and the live cycle assessment which aims to quantify the environmental impacts of a product from 'cradle' to 'grave', is integrated that builds life cycle activity analysis (LCAA) methodology. The following section describes the Antecedents of LCAA and presents the main characteristics of the LCAA approach.

5.3 Life Cycle Activity Analysis: Antecedents and Characteristics

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[10] Note that the use of the term "life cycle" in the environmental literature is quite different from the concept of the life cycle of a product used in the business literature (the cycle from the market introduction to the obsolescence).

Activity Analysis (AA) was developed by Koopmans in the early fifteens, (Koopmans, 1951, 1957). For this pioneering work, Koopmans received the 1975 Nobel Prize in economics (shared with I. Kantorovich). However, the original formulation was not well suited for numerical solution, since it assumed that there were as many commodities as activities, and that the resulting system of equations had a non-singular solution. A major step was the reformulation of AA as a Linear Programming (LP) problem, permitting any number of activities and any number of commodities, (Charnes and Cooper, 1961).

In an Activity Analysis model, the possible techniques of production available to a firm, or to the economy as a whole, are given by a finite list of elementary activities that can be used simultaneously and at arbitrary non-negative levels. The resulting production possibility set is a polyhedral cone. The activity analysis model, a generalization of the Leontief input/output model, can be used to generate a large number of distinct linear programs, depending on the objective function to be chosen and on the specific set of factor endowments.

Activity Analysis can be viewed as a tool of partial economic analysis modeling for the representation of an industry or a sector of the economy, providing a mathematical format suitable for the representation of an entire vertical production chain, (Thore, 1991). More recently, (Heijungs, 1996, 1997) recognized the conceptual similarities between LCA and classical Activity Analysis (AA) and observed that Life Cycle Inventory is an extension of AA, both being “commodity-by-industry analysis”, generally seen as superior to other forms of inter-industry analysis, (Heijungs, 1996), however no connection between mathematical programming and LCA was made. Thus, a major purpose of LCAA discussed here is to highlight how this connection can be established, using extended mathematical programming formats of AA for an integrated economic and environmental analysis of the life cycle of products.

For example, whenever products can be manufactured in alternative ways, distributed through alternative marketing channels, reused or recovered, there exists scope for choice and for controlling the environmental impacts. By combining the LCA approach with mathematical programming techniques, it is possible to represent these options explicitly along the whole supply chain and to solve for optimal economic (e.g. production levels or profit) and environmental performance (e.g. environmental impacts and allocation of resources).

The classical formulation of AA distinguishes three classes of goods: primary goods (natural resources, materials or labor), intermediate goods (outputs which serve as inputs into subsequent activities) and final goods (outputs). LCAA extends the concept of linear activities to embrace mass and energy fluxes over the entire life cycle of products. In particular, the proposed LCAA model includes one additional category: “environmental goods”, representing primary resources (material or energy drawn directly from the environment) and emissions of pollutants and the disposal of waste (discarded into the environment without subsequent human transformation).

In the LCA terminology, the “environmental goods” are known as environmental burdens and they can be further aggregated into categories of resource usage and environmental impacts, such as global warming, ozone depletion etc. The purpose of such aggregation is two-fold. Firstly, it interprets the environmental burdens included in the output table in terms of environmental problems or hazards. Secondly, by aggregating a large set of data into a smaller number of impact categories it simplifies the decision-making process.

The concepts of "foreground" and "background" proposed within the environmental systems analysis theory are very useful since they help to distinguish between unit processes of direct interest in the study, and other operations with which they exchange materials and energy, (Clift et al., 2000). The foreground may be defined as the endogenous part of the production chain, which includes the set of processes whose selection or mode of operation is affected directly by the decisions of the study. The background denotes the exogenous parts of the production chain, comprising all other processes that interact directly with the foreground system, usually by supplying material or energy to the foreground or receiving material and energy from it. These concepts are illustrated in Figure 5.2.

Adopting these concepts and terminology, a complete life cycle approach must pursue the production chains both upstream (all the way to their "cradle") and downstream (to their "grave"), by explicitly encompassing the indirect effects associated with the supply of goods together with direct effects of the core system being modeled. Thus, the total environmental impacts are calculated over both the endogenous and the exogenous part of the life cycle. The foreground and background concepts are also useful in setting goals and targets which can be attached to both variables in the foreground and in the background.

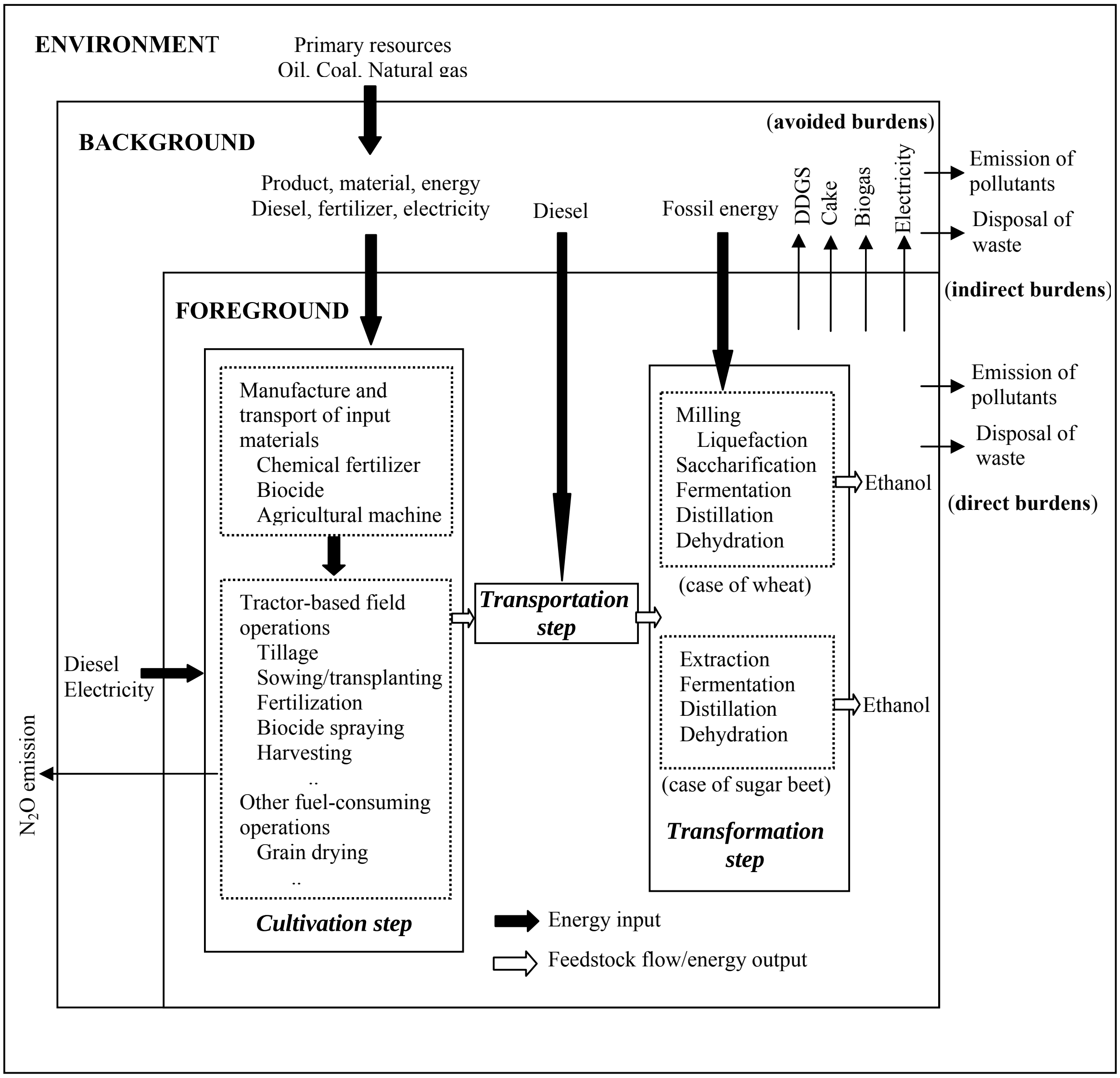


Figure 5.2 Foreground and background systems

Varying the numerical assumptions of the model (and varying the goals or the priorities parametrically), LCAA can be used to generate a set of scenarios to be presented to the policy-maker. In this manner, a series of "what if?" questions can be addressed and answered.

The conceptual foundations for LCAA are evident and have been described in the beginning of this section. However, it should be noted that the research methodology followed has mainly been “applications-driven”, meaning that relevance was attained by starting with concrete problems in the context of actual applications. The analysis of mathematical programming formats that can be formulated within the LCCA framework is presented in the next section.

5.4 Mathematical Programming Formats

Notation

A	matrix of input coefficients; each element denotes the quantity of an input required to operate an activity at unit level
B	matrix of output coefficients; each element is the quantity of an output obtained when an activity is operated at unit level
c	row vector of unit costs of operating the various activities, it is known and given
d	column vector of final demand, it is known and given;
D	matrix of unit environmental burdens; each element is the environmental burden generated in the upstream processing, transportation and manufacture of one unit of primary goods
$F(j,i)$	matrix of relative environmental impact coefficients
g	a vector of environmental goals defined in terms of burdens
g'	a vector of goals defined directly in terms of environmental impact categories, $g' = F(j,i) \cdot g$
p	a row vector of unit prices of recovered goods
q	a row vector of unit costs of primary goods
w	a column vector of supply levels of primary goods, such as material and energy from the background system
x	a column vector of unknown activity levels
y	a column vector of unknown levels of recovery of intermediate goods; zero entries indicate recovery entirely in the foreground, positive entries indicate recovery supplied from the foreground to background

Superscripts

E	"environmental goods"
F	final goods
I	intermediate goods
P	primary goods

Depending of the type of applications and problems to be addressed, different types of models can be formulated. For example, many alternative objective functions can be specified (or even a multi-objective approach) using linear and non-linear programming techniques. Two simplified versions are presented as illustrative examples of the type of programming models that can be formulated. The first version considers only closed loops while the second one includes the possibility of open-loops (recovery from the foreground to the background).

The LCAA model uses an input-output format. A detailed notation list can be found at the end of the paper. A basic mathematical format of LCAA can be written as the following linear program:

$$\begin{array}{lllll} \text{min} & cx + qw & & & \\ \text{subject to} & -A^{P}x + w & \geq & 0 & \\ & (-A^{I} + B^{I})x & = & 0 & \\ & B^{F}x & \geq & d & (1) \\ & (A^{E} - B^{E})x - Dw & \geq & -g & \\ & x, w & \geq & 0 & \end{array}$$

where (see also Notation in the Appendix IV) cx represents the total costs of operating the activities x and qw is the total cost of primary goods. A and B are matrices of input and output coefficients, respectively; w represents a column vector of supply levels of primary goods, such as material and energy from the background system. Superscripts P, I, F and E represent primary, intermediate, final and “environmental goods”, respectively. Primary goods are inputs of products, material and energy produced in the background. Intermediate goods are outputs that serve as inputs into subsequent activities, either in the foreground or in the background. Final goods are the functional outputs delivered by the distributed and purchased products, the production of which is the objective of the economic system under study. “Environmental goods” or interventions are flows of materials or energy drawn from or discarded into the environment without subsequent human transformation. By convention, the input coefficients (A-coefficients) have a minus sign and the output coefficients (B-coefficients) are assigned a positive sign. Consequently, matrices A and B become partitioned into:

$$A = (-A^{P}, -A^{I}, 0, -A^{E}) \qquad (2)$$

$$B = (0, B^I, B^F, B^E)$$

As discussed in the previous section, the model adopts the concept of the foreground and background systems (see Figure 1). The foreground is modeled in some explicit detail: the production activities themselves, and the conversion of intermediate goods into final goods, i.e. the set of processes whose selection or level of operation can be affected directly by decisions in the study. The background comprises the exogenous flows of the model, i.e. the supplies of primary goods.

The "environmental goods" or interventions arising from the foreground (i.e. from the operations which are being modeled directly) are termed *direct burdens*. They include the direct emissions from operating the activities (e.g. combustion, chemical reactions, thermal treatments, long-term leachate emissions from landfill etc.) and from the transportation of intermediate goods. The resource usage and emissions arising from the background activities are termed *indirect burdens;* they are caused by the changes in the demand of products, materials and energy in the foreground. The indirect burdens can be described by generic industry data, obtainable from commercial or public life cycle inventory databases. Direct burdens on the other hand are process-specific and must be sourced from the manufacturers in the foreground.

In this way, the model calculates the total accumulated environmental burdens over the entire life cycle of the product, including the indirect environmental burdens of primary goods arising in the background. Thus, the total environmental burdens arising over the life cycle of the products are equal to the sum of the foreground (direct) burdens and the background (indirect) burdens, that is $(-A^E + B^E)x + Dw$, where Dw is a vector of environmental effects arising from the background.

The model (1) minimizes total costs, which comprise the costs of operating activities and of primary goods. For present purposes, it is assumed that the prices of all primary goods are known and constant.

The crucial feature of formulation (1) is the constraint $(A^E - B^E)x - Dw \geq -g$, which requires the environmental burdens $(A^E - B^E)x - Dw$ not to exceed a vector of environmental goals g set for example by a policy- or decision-maker.

The second version of an LCAA mathematic programming format involves expanding the possibilities for reuse and/or recovery of products. As mentioned before, such loops in the life cycle chain can take two forms: recovery entirely in the foreground (closed loop) and recovery from the foreground to the background (open loop). Materials and energy recovered in the foreground, which are also inputs to the activities in the foreground (closed loops), may lead to the avoidance of environmental burdens. This is the case when burdens associated with foreground activities that are displaced by the recovery processes are higher than the burdens of the recovery itself. The opposite is also possible: material loops may sometimes lead to higher environmental burdens, i.e. a worse environmental performance overall. This can happen when the recovery of used products and materials by itself imposes considerable burdens.

A product that is recovered and exchanged with the background system will be treated as an intermediate good. The usual assumption is that the recovery of materials and/or energy in the foreground does not affect the demand for goods and services in the background (except for materials and energy supplied to the foreground activities), (Clift et al., 2000). Therefore, the market balance for intermediate goods which was defined in (1) as $(- A^I + B^I)x = 0$ has to be amended to $(- A^I + B^I)x - y = 0$, where y is a column vector of unknown levels of recovery of intermediate goods. Zero entries indicate recovery entirely in the foreground, positive entries indicate recovery supplied from the foreground to background.

Adopting these assumptions, the total environmental burdens are then equal to the sum of the foreground (direct) burdens and the background (indirect) burdens minus the avoided burdens, that is: $(B^E - A^E)\, x + Dw - Dy$.

Regarding economic considerations, when recovery or reuse occurs entirely in the foreground, no additional net revenues or costs accrue, since these economic flows have already been taken into account in the activity analysis format. However, when intermediate goods are recovered back to the background and thus “exported” to the exogenous part of the model, it is necessary to account for the net revenue (or net cost) py, collected in the foreground, where p is a vector of unit prices of recovered goods. Here, p is assumed to be known and to represent average prices of recovered goods. (Alternatively, marginal prices or price sensitive functions could be used, describing the price elasticity of recovered goods. The latter extension would cause the model to change from a linear to non-linear one.) Combining these changes to accommodate recovery of goods, the programming format (2) becomes:

$$
\begin{array}{lllll}
\text{min} & cx + qw - py & & & \\
\text{subject to} & -A^P x + w & \geq & 0 & \\
 & (-A^I + B^I)x - y & = & 0 & \\
 & B^F x & \geq & d & \qquad (3) \\
 & (A^E - B^E)x - Dw + Dy & \geq & -g & \\
 & x, y, w & \geq & 0 &
\end{array}
$$

Programming format (3) represents the extended LCAA format, accounting for the possibility of closed-loops. Further extensions to these two basic model are possible. For example, transportation and shipping of goods between various locations may be accounted for in all parts of the supply chain. The basic programming format still applies, treating each transportation link as a separate activity, with its own inputs and outputs, (Freire et al., 2001). Moreover, if the time-profile of activities is important, the model may be developed into a multi-period one. All variables then need to be dated, and the market balances in each time period need to be defined explicitly.

Environmental Life Cycle Impact Assessment

The B^E and $-A^E$ matrices constitute an inventory table, summing up the outflows and subtracting the inflows of “environmental goods” associated with the economic activities. In LCA, this is part of Inventory Analysis.

Flows of substances are recognized as environmental problems only when they pose problems to the environment and society. Thus, there is an intrinsic value-bound aspect to the definition of an environmental problem, (Heijungs, 1997). To deal with this, it is necessary to establish scientific relationships between pollutants and a set of environmental impact categories, such as the greenhouse effect, acidification or ozone layer depletion. Similarly, there is a relationship between resource extraction and various depletion problems. Hence, the impact categories can be defined in terms of damage to the environment by pollutants in air, water or soil and by the depletion of available natural resources. In LCA terminology, aggregation of environmental burdens into impact categories is carried out in the Impact Assessment phase.

As described by the environmental-goal constraint in the extended program (3), the vector of environmental burdens, *E(i),* is equal to the sum of all direct and indirect burdens minus the avoided burdens:

$$E(i) = (B^E - A^E)x + Dw - Dy$$

where i represents individual environmental burdens. The individual burdens can be aggregated into a set of environmental impact categories according to the expression:

$$I(j) = F(j,i) \cdot E(i)$$

where I(j) is a vector of environmental impact categories j and F(j,i) is a matrix of relative impact coefficients (for example, the global warming impact coefficients of greenhouse gases are expressed relative to CO_2, whose coefficient is defined as unity).

The environmental goal-oriented expression may then be reformulated into:

$$F(j,i) \cdot [(A^E - B^E)x - Dw + Dy] \geq -g'$$

where g' is a vector of goals defined directly in terms of environmental impact categories:

$$g' = F(j,i) \cdot g$$

5.5 Modelling of the Bio-fuel Production System

A partial equilibrium economic model based on mathematical programming principles (OSCAR[11]) was built in order to assist in the micro and macro-economic analyses of the

---

[11] OSCAR : « Optimisation du Surplus économique des Carburants Agricoles Renouvelables »

multi-chain system of the bio-fuel industry. The model has been designated by *Life Cycle Activity Analysis* (LCAA), being based on the integration of Activity Analysis - a well-known procedure in economics - with the environmental Life Cycle Assessment methodology, which aims to quantify the environmental impacts of a product from 'cradle' to 'grave'.

The integrated micro-economic model represents agricultural supply sector and industrial configuration optimization simultaneously. The model also estimated CO_2 emission and cost of CO_2 saving at optimal. Partial equilibrium agricultural sector modelling and engineering approaches, applied to the industrial model, are jointly exploited to determine the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply. The most efficient farmers will provide beet and grain at the lowest possible prices. (Rozakis et al., 2002) adopted a partial equilibrium economic model in order to assist in the micro and macro-economic analysis of the multi-chain system of the biofuel industry in France under environmental Life Cycle Assessment (LCA) framework.

5.5.1 Formation of Agricultural Model

A linear programming model is developed for this study that simulates decision making in agricultural farming. The optimization results provide efficient organization of each farming unit. In the optimum solution when the base year optimal crop mix approaches the actual one, then the model can be expected to forecast future changes given specific policy parameters and reveal impacts of different policy scenarios on production volume, resource allocation and farm income, eventually evaluating policy efficiency. Moreover, optimization analysis is theoretically appealing as it generates shadow prices for explicit capacity as well as policy constraints providing valuable information to policy makers. However, in most cases, it is replicate actual base year data, due to limitations inherent to linear programming (Rozakis et al., 2008a). The limitations and disadvantages of linear programming in modeling usally mentioned in the literature as cited by (Lehtonen, 2001) are: a) normative optimization behavior due to strict neoclassical assumptions, b) aggregation problem,)c) ad hoc calibration and validation procedure, d) discontinuous response to changing endogenous conditions, and e0 tendency to strong specialization.

In order to mitigate the above deficiencies, the model developed in this study is sufficiently detailed to reflect the diversity of arable agriculture, articulating hundreds of farm sub-models in a block angular form, that have neither the same productivity nor the same economic efficiency so that the production costs are variable in space. For this reason,, ex-post aggregation helps to avoid problems arising from the sector representation (discontinuous response, overspecialization) from a single representative farm, which does not consider heterogeneity phenomena. Consequently, the average cost is not considered equal to the marginal one, and marginal behavior can be inferred for the sector.

The model is calibrated via crop rotation constraints as well as flexibility constraints used to avoid arbitrary and non-explicit adjustments or ad hoc parameters and data manipulations. In the present study, crop rotation constraints applied are specified by agronomic practices appropriate to the examined cropping system in Greek conditions. In the Greek arable cropping system, demand of alfalfa that is particularly elastic according to the wholesales, replaced fixed price in the objective function that rendered the linear programming model to a quadratic form.

5.5.1.1 General Structure of the Agricultural Model

Structurally the model is written in “block angular” forms. Each farm is suppose to choose a cropping plan and input use among technically feasible activity plans independently so as to maximize gross margin. The objective function includes all the variables (activities in different farms) while the constraints is shaped by tables of technical coefficient, diagonally placed in scalar form, where each table refers to a representative farm separately. Thus, each farm is treated independently.

Each agricultural farm (f) is supposed to choose a cropping plan (x^f) and input use among technically feasible activity plans $A^f x^f \leq b^f$ so as to maximize gross margin (gm^f). The cropping plan is to decide much acres from each crop (c) will be cultivated. The optimization problem for the farmer f appears as:

$$
\begin{cases}
\max\limits_{x^f} gm^f\left(x^f, \theta^f, \kappa\right) \equiv g^f\left(\theta^f, \kappa\right) x^f \equiv \sum\limits_{c} \left(\left(p_c^f + s_c\right) y_c^f + sub_c - v_c^f\right) x_c^f \\
s.t. \_\_\ A^f\left(\theta^f, \kappa\right) x^f \leq b^f\left(\theta^f, \kappa\right) \_\_\_\ A \in \Re^{m \times n} \ \_(I) \\
x^f \geq 0 \ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ x \in \Re^n \ \_\_(II)
\end{cases}
$$

The model contains f farm problems such as the one specified above. The gross margin is derived if the variable cost (v_c^f) is deduced from the total farm income as appear from the first equation above. The basic farm problem is linear with respect to x^f, the primal $n \times 1$ vector of the n cropping activities. The $m \times 1$ vector b^f contains the upper limits of constraints of the farm while the m×n matrix A^f contains all the technical coefficients that are related with the *m* constraints and *n* crops. The vector θ^f represents the parameters related with the fth agricultural farm and *k* represents general economic factors. More analytically, y_c^f is the output of each crop (kg/ha), p_c^f is the price of sale dependent on quantity (€/kg), v_c^f is variable costs, s_c is the subsidy given per kg (€/kg) and sub_c is the subsidy specific to crops given per ha (€/ha).

The constraints can be distinguished in relation with resource, agronomic, demand and policy ones. Main constraints are: available land (both total land area and area by land type such as irrigated, non irrigated etc.), irrigation water availability constraints, crop rotational constraints, environmental constraints, and so forth. Detailed algebraic notation of the model constraints and objective function along with associated indices, parameters and decision variables are presented in the Appendix VI (Haque et al., 2009).

5.5.1.2 Non-linearity in the Agricultural Model

The equations derived above is evidenced by its form, is a linear equation and applicable for the crops which demand is constant. Market demand for certain products may price sensitive. In the Greek arable sector, non-linear market demand is applicable in the case alfalfa which demand is sensitive to price. The alfalfa is quite bulky, difficult to transport to abroad and the price is determined in the domestically. There is a limit of quantity that it can be sold and be absorbed in the domestic market depends on the domestic demand, i.e., the quantity of livestock ruminative that will consume it.

The market demand for alfalfa which are sensitive to price changes is given by the following linear relationship:

$$p_i = a_i - b_i \cdot q_i$$

Where p_i and q_i is the price and quantity demanded, respectively, while a is the constant for each product and b is the slope of the demand curve, respectively.

Each demand side function is integrated and the resulted integrals are all summed together. Equation for the demand for the alfalfa we have in the following form:

$$a_{alf} \cdot Q_{alf} - 0.5 \cdot b_{alf} \cdot Q_{alf}^2$$

The value for a and b for alfalfa that were used in the model is 0.18 and 6×10^{-11}, respectively.

The objective function is modified to accommodate available non-linear demand curves so that the model becomes non-linear (quadratic):

$$\max_{x^f} \sum_{cp} \left(\left(p_{cp}^f + s_{cp} \right) y_{cp}^f + sub_{cp} - v_{cp}^f \right) x_{cp}^f + \sum_{ce} \left(\left(a_{ce} - \frac{b_{ce}}{2} \sum_f w_f y_{ce}^f x_{ce}^f \right) y_{ce}^f - v_{ce}^f \right) x_{ce}^f$$

The set of crops in the model which demand curve is linear is denoted by *cp* while the crops with nonlinear demand function denoted by *ce*.

The model is run in three simulations; every simulation is conducted for maximization of gross margin subject to a set of constraints. Firstly the model is run given the CAP policy in force in year 2002 (base year) that constitutes the validity of the model developed. The results that are derived from the model (type of crop and how much acres from each crop in each sample farm) are compared with the observed cultivated area in the farms of the sample in 2002. If the optimization results approximate those observations in satisfactory degree then it means that the model developed can make enough precise forecasts.

The second and third simulations take into consideration the changes of revised CAP (decoupling, cross compliance) and calculates the optimal crop mix for maximizing total gross margin under restrictions. The difference between these two simulations is that in the second simulation, alfalfa demand is considered linear while in third the demand is considered nonlinear. The reality for the alfalfa demand is somewhere in between, for this reason both cases are examined.

5.5.1.3 Estimation of Variable Cost per crop

As it appears from the objective function of the model, the knowledge of variable cost for each crop is essential for the calculation of gross margin of each farm. The estimates of variable costs per crop and farm mostly rely on the micro-economic farm data published by the Farm Accountant Data Network (FADN) combined with survey data. The problem with the FADN statistics is the variable cost that refers on expenses at the farm level not directly related to specific crop; it is variable cost in total at the farm level. For, example, expenses for fertilizers are precisely reported as a sum with no indication of how much is spent on fertilizers used in wheat cultivation. It is essential to transform variable cost per farm to variable cost per crop per farm to use in the model. For this reason a goal programming model is build adopted from (Guinde et al., 2005) using FADN data. This model is also written in GAMS code (Appendix V).

The first step before the application of the model is to find out variable costs that concern only for the arable crops. Every sample farm is activated in various sectors like animal stock farming, horticultural crop cultivation, olive groves, vines etc. The part from the total variable costs related with the arable crops is concern for this study.

For this purpose, segment of farm income from the sale in each sector is used as base. That is, the estimation of variable costs was based on a percentage of total sales of each activity. Activities of the farms were divided into 6 categories: arable crops, vegetables, trees, vines, animals and finally remainder. Thus, if a% is the percentage of sales revenue for arable crops for the f farm, a% will be also the percentage of each variable cost for the arable crops. It is natural that the discounting is an approximation of actual size.

One problem that arises however is that certain categories of costs related only to specific categories of activities. This is best illustrated in the following example: Suppose a% is the percentage of sales on arable crops and b% is the rate for the category "animals ". By the above logic, if K is the variable cost of category "Crop Protection Products", then the corresponding variable costs for arable crops is a% × K . The mistake here is that the variable cost "crop protection products" has no relation with the category "animals". Thus the percentage of sales for the category "animals" should not reduce the corresponding figure for arable crops and consequently their share in variable costs "crop protection products.

General note:

If

Σ: total sales

A: sales related with arable crops

X: sales not related with examined costs

K: the variable cost "crop protection products"

then *a* proportion of variable costs for arable crops is:

$$\mathrm{a} = \frac{\mathrm{A}}{\Sigma - \mathrm{X}} 100\%$$

Then *a* is multiplied by the *K*.

This conversion is applies for all farms and thus the variable costs related to the whole farm converted to variable costs that concern only the arable crops. This is translated in a goal programming model solved in each farm where the weighted sum of deviations is minimized subject to constraints:

$$\begin{cases} \min \sum_{c \in C} w_c \left(\overline{\delta}_c^{f} + \delta_c^{+f} \right) + \sum_{i \in I} \left(\overline{\phi}_i^{f} + \underline{\phi}_i^{+f} \right) \\ s.t.\_\_\_ v_{c,i}^{\max} \geq v_{c,i}^{f} \geq v_{c,i}^{\min} \_ \forall c \in C \_ \forall i \in I \\ \sum_{i \in I} v_{c,i}^{f} - \overline{\delta}_c^{f} + \delta_c^{+f} = \bar{v}_c \_\_\_\_ \forall c \in C \\ \sum_{c} v_{c,i}^{f} - \overline{\phi}_i^{f} + \underline{\phi}_i^{+f} = V_i^{f} \_\_\_\_ \forall i \in I \end{cases}$$

Where:

Set I:= {seeds, fertilizers, phyto-sanitary, fuels and lubricants, electricity, water, machinery rent, labour wage}

$v^{f}{}_{c,i}$:	variable cost of category *i* in farm *f* related to crop *c*
$\bar{v}_c$:	variable cost per crop, regional average
V_i^{f}:	total variable costs of category *i* in farm *f*

δ^{+},δ^{-}	positive and negative derivations from the average variable cost per crop *c*
ϕ^{+},ϕ^{-}	positive and negative derivatives from variable cost of category *i* for farm *f*
$v_{c,i}^{\max},v_{c,i}^{\min}$	maximum and minimal variable costs per crop *c* and category *i* reported in surveys
$w_{c}\in[0,1]$	preference weights corresponding crops that take values between 0 and 1 depending on the importance of each crop in the farm income.

With this way the variable costs per crop for each agricultural farm is determined which are also used in the objective function of the mathematical programming model of arable farming for the calculation of gross margin.

5.5.2 Industry Sector Model

Industrial model for optimization of bio-energy conversion seek to determine optimal plant size and technology. This model is tied together with the agricultural sector model that already described in the previous section, to give us the optimal solution, i.e., the optimal capacity of the plant. The coexistence of the two models is to meet the highest satisfaction of the two stakeholders of the present study i.e., the farmers who will supply raw materials (sugar beet and wheat) seeking the best possible price, and the industry, who wants to buy its raw materials at minimum possible cost.

Profit maximization of the industrial unit determines the optimal size and technical configuration of the plant, giving maximum income from sales of product and by-products and minimal cost of production. The industrial unit will produce the quantity of ethanol (t EtOH / year) which gives maximum revenue from sales and minimum cost of production. This quantity depends on the quantity of sugar beet and wheat grain to be supplied in the industry and on the price also.

The main relationships shaping the feasible area of the industry model deal with capacity, sugar-beet to wheat ratio to ensure maximal duration of operation during the year, and capital cost linked to size (average capital cost is decreasing for increasing ethanol capacities). Usually size determination is modeled by binary or integer variables, as in a bio-energy application (Mavrotas and Rozakis, 2002) that also mentions a number of studies of the same kind. In this study, since a continuous relationship is available (Soldatos and Kallivroussis, 2001) we preferred to introduce exponential terms (scale coefficients) in the objective function rendering the industrial module non-linear also. Furthermore, feedstock supply i.e., wheat and sugar beet produced in farms, have to satisfy industry needs (raw material demand should be greater than supply). A number of balance constraints concerning by-products, material inputs and environmental indices (such as water for irrigation) complete the constraint structure.

To ensure maximum duration of operation (330 days) during the year, proportion of feedstock used is rationalized. Ethanol production from sugar beet is seasonal activity because sugar beet is frail enough at the storage (they degraded very fast by micro-organism). Generally sugar beet harvesting is started from September and the factory may run with it for roughly 100 days. For the remaining 230 days, the factory will run with wheat feedstock that can be stored and be used for any time period. The daily ethanol production will remain the same for each day regardless of what feedstock is used.

This proposition is expressed as restriction in the model with the following relation, where the numerators represent production of ethanol in tons per year from wheat and sugar beet.

$$\frac{\mathrm{EtOH}_{(\mathrm{wheat})}}{230} = \frac{\mathrm{EtOH}_{(\mathrm{sugar\ beet})}}{100}$$

The LIBEM (Liquid Biofuels Evaluation Model)-Bioethanol model (Soldatos and Kallivroussis, 2004) is used as the basis for the development of industrial model which is briefly presented below.

5.5.2.1 The LIBEM Bioethanol Model

LIBEM-Bioethanol model is designed to analyze economic and financial aspects of bioethanol production from a variety of feedstock, e.g. corn, wheat, sugar beet. In its initial form, the model was concerned to the production of ethanol from starchy material like wheat and corn, but thereafter suitably modified for the raw material wheat and sugar beet (Maki, 2007).

The model is developed so as to:

- Quantify bioethanol production from available feedstock
- Derive production cost of bioethanol
- Derive financial analysis for economic life of bioethanol plant.

The model takes into account all the technical and economic parameters e.g. transformation efficiencies, required resources, useful economic life, purchase costs of raw materials and utilities, selling prices of product and by-products, etc. relevant to a bioethanol plant. Most of the variables can be changed accordingly in order to reflect processing technology performance and local economic conditions.

Variability in ethanol production process from wheat and sugar beet

Bioethanol is produced biologically by the fermentation of carbohydrate material. However, production process of ethanol from starchy material like wheat and from sugar containing material like sugar beet is varied.

5.5.2.1.1 Ethanol production from wheat

For the production of ethanol from wheat, dry milling industrial transformation processes is considered in the analysis. The process includes the following stages:

- Milling
- Enzyme liquefaction of the starch present in the grain
- Sacharification
- Fermentation
- Distillation and dehydration
- By-products recovery

The clean wheat is ground and mixed with water to form a mash. The mash is cooked, and enzymes are added to convert starch to sugar, then yeast is added to ferment the sugars, producing a mixture containing ethanol and solids. The beer (ethanol-water mixture) is then distilled and dehydrated to create 99.5% ethanol. The solids remaining after distillation are dried to produce distillers' dried grains or distillers' dried grains with soluble (DDGS, which is assumed to be sold as a protein-enriched feed ingredient.

5.5.2.1.2 Ethanol production from sugar beet

The production process of ethanol from sugar beet is simpler than from wheat as the sugars are readily available for fermentation. The process includes:

- Extraction
- Fermentation
- Distillation and dehydration
- By-products recovery

After cleaning, washing and chopping, beet slice passed into a 'diffuser' to extract the sugar into a hot water solution. The liquid exiting the diffuser is called 'raw juice'. In a combined sugar/bioethanol production process, sugar is extracted from the raw juice. Alternatively, sugar syrup may be produced directly from sugar beet by cooking shredded sugar beet for several hours and then pressing the resulting beet mash and concentrating the juice. Afterwards the extraction, yeast is added to ferment the sugars and then distillation and dehydration procedure take place. Sugar beet pulp is the most important by-product of the sugar beet conversion process. Generally the pulp is pressed and dried and sold as animal feed.

5.5.2.2 Model description

The LIBEM model is written in Microsoft Office Excel Workbook and analyzes the economics of ethanol production from biomass. It consists of two modules (spreadsheets): Production and Finance. The bioethanol module includes various technical and economic information with regard to the production of ethanol from wheat and sugar beet while the financial module presents a comprehensive economic analysis of the industrial unit and various information related to the investment. The LIBEM model is presented in Appendix VII.

5.5.2.2.1 Production Module

Bioethanol module consists nine sections, namely General Information, Feedstock Data, Specific Consumption of Raw Materials and Utilities, Technical Data of EtOH Plant, Capital Cost Detail, Personnel detail, Raw Materials and Utilities Detail, Average Inventories and Miscellaneous Operating and General Expenses Detail.

The major information contained or produced in the module includes:

- Quantity and composition of feedstock input into the process
- Size and capital costs of processing plant
- Consumption and cost of raw materials and utilities
- Quantity and selling prices of products and co-products
- Labour requirements
- Miscellaneous operating and administrative expenses

The main computations performed by the Production Module involve the derivation of size and capital costs of ethanol plant and of the production and administrative expenses.
The main computational steps are:

- Firstly the required data must be input into the module e.g. quantity and cost of the available feedstock, etc.
- The next step involves the calculation of the performance of producing ethanol from feedstock e.g. wheat and sugar beet.
- Then the calculation of ethanol plant capacity as a function of feedstock quantity and ethanol yield is performed.
- After that it computes the capital costs by applying a combination of methods commonly used in process costing (the capacity ratios raised to an exponent and equipment factored estimates) and assuming values for construction, engineering and contingency components.
- The next calculations concern the costs and usage of raw materials and utilities and the required personnel as a function of the plant capacity.
- The last step concerns the computation of miscellaneous operating and administrative expenses based on direct plant costs, operating labor costs, etc.

A flowchart showing the main computational steps is given in Figure 5.1.

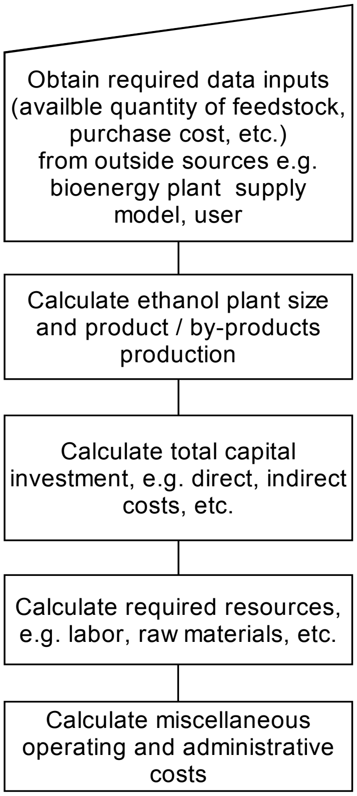


Figure 5.1. Flowchart of bioethanol module

Characteristics of Feedstock

Characteristics of feedstock e.g. moisture content and starch content, earth content is specified in this section. Feedstock data are presented in the Table 5.1.

Table 5.1. Feedstock characteristics

Feedstock	Moisture content %wet basis	Earth content %	Starch content % dry weight basis	Sugar content %
Wheat	10%	-	65%	-
Sugar beet		20%	-	14.3%

Specific consumption of raw materials and utilities

Feedstock: The specific consumption of feedstock is the amount of feedstock needed for the production of one unit ethanol. Rate of feedstock consumption per unit of ethanol production is shown in Table 5.2.

Table 5.2. Feedstock consumption per ton of ethanol production.

Feedstock	Specific consumption (t/t EtOH)
Wheat	3.34
Sugar beet	14.94

Chemicals and enzymes consumption rates are taken from equipment manufacturers (VOLGELBUSH, etc.) and are assumed to be independent of plant size. Consumption rate of chemicals and enzymes and other raw materials are presented in Table 5.3.

Table 5.3. Chemicals enzymes and other raw materials consumption rates.

Item	Consumption rate for EtOH from wheat (Kg/t EtOH)	Consumption rate for EtOH from sugar beet (Kg/t EtOH)
Caustic soda	44.00	-
Sulphuric acid	19.00	11.35
Calcium chloride	2.50	-
Diammonium phosphate	3.80	-
Antifoaming agent (oil)	0,10	2.04
A-Amylase	1.40	-
Gluco-Amylase	2.00	-
Yeast	0.70	0.70
Make-up water (m^3)	6.20	8.60
Phosphoric acid	-	0.36
NaOH	-	2.39
Urea	-	0.45

Utilities: Steam and electricity

The predominant energy requirement of an ethanol plant is the steam required for the distillation process. Steam is usually used both to heat the mashed grain to produce ethanol and to dry co-product, distillers grain to produce DDGS from wheat and pulp from sugar beet. The consumption rates for electricity and steam are shown in Table 5.4. Note that 72 kg fuel oil is required to produce 1 ton of steam.

Table 5.4. Utilities consumption rates.

Item	Unit	Consumption rate for EtOH from wheat (Unit/t EtOH)	Consumption rate for EtOH from sugar beet (Unit/t EtOH)
Electricity	kWh	503	228.7
Steam	t	5	4.42

Technical data of EtOH plant

Products and by-products yields

Ethanol yield: Ethanol yield is dependent on the starch content in the wheat grain and sucrose content in the sugar beet. It is calculated by taking into consideration the theoretical ethanol yield from starchy materials and an overall conversion efficiency of starch to ethanol. On the other hand theoretical ethanol yield from sugar containing materials is dependent on overall conversion efficiency of sucrose to ethanol. The parameters considered in the calculations are shown in Table 5.5:

Table 5.5. Technical coefficient for conversion of ethanol from feedstock

Item	Starchy material (wheat)	Sucrose (Sugar beet)
Theoretical ethanol yield	0.568 t/t starch	0.538 t/t sucrose
Overall conversion efficiency	90%	87%

The actual yield of ethanol from wheat is calculated by using the formula:

$$Y_{EtOH} = (1 - MC) * SC * CEF * Y_{theoretical}$$

where: Y_{EtOH} = *Ethanol yield, t EtOH / t wheat*

MC = Moisture content, % (decimal format)

SC = Starch content, % (decimal format)

CEF = Overall conversion efficiency of starch to EtOH, % (decimal format)

$Y_{theoretical}$ = *Theoretical yield of ethanol from starchy material, t EtOH/t wheat*

The actual yield of ethanol from sugar beet is calculated by using the formula:

$$Y_{EtOH} = (1 - EC) * SC * CEF * Y_{theoretical}$$

where: Y_{EtOH} = *Ethanol yield, t EtOH / t sugar beet*

EC = Earth content, % (decimal format)

SC = Sugar content, % (decimal format)

CEF = Overall conversion efficiency of starch/sucrose to EtOH, % (decimal format)

$Y_{theoretical}$ = *Theoretical yield of ethanol from sucrose containing material, t EtOH/ t sugar beet*

The current values of EtOH yields are as follows:

wheat: 0.299 t/t grain

sugar beet: 0.067 t/t sugar beet

By-product yield: DDGS is produced from ethanol production process with grain as by-product. On the other hand Pulp is produced in the ethanol production process with sugar beet.

Production rates are considered independent on the plant size and are currently valued as follows:

DDGS from wheat:	0.320 t/t grain
Pulp from sugar beet:	0.203 t/t sugar beet

Plant capacity

The calculation of ethanol facility size, at any site, is based on the amount of available feedstock at plant gate and the expected ethanol yield.

The model estimates the capacity and consequently the capital costs if the available feedstock is enough to build a plant with annual ethanol production between 10,000 t and 120,000 t. The capacity of an ethanol plant is determined by dividing the available quantity of feedstock by the ethanol yield.

The plant capacity is estimated by using the following formula:

$$S_{EtOH\ plant} = Q_{feedstock} \times Y_{EtOH}$$

Where: $S_{EtOH\ plant}$ = *Ethanol plant capacity, t EtOH/year*

$Q_{feedstock}$ = *Available feedstock quantity, t/year*

Y_{EtOH} = *Ethanol yield, t EtOH / t feedstock*

Capital Cost Analysis

The total capital investment includes the total capital costs (direct and indirect costs, contingency), interest expenses during construction, and start-up costs. Working capital is estimated in the financial analysis.

Direct costs include the costs of process and auxiliary equipment, purchased-equipment installation, instrumentation and controls, piping, electrical equipment and materials, buildings, site improvements, service facilities and land. Process and auxiliary equipment include feedstock preparation and handling equipment, milling equipment, liquefaction-saccharification and fermentation equipment, distillation-evaporation-dehydration equipment, decantation and drying equipment, air compressor, steam boiler, cooling towers, etc. *Indirect costs* include engineering-supervision costs and construction expenses.

<u>Land</u>

Area requirements vary depending on various factors such as feedstock storage, waste water treatment, product and co-products storage, etc. The area required for establishing an ethanol plant is not linearly increased with the size of the plant. The present study is conducted for the conversion of a sugar factory to bioethanol plant, hence land is readily available and land cost is not included in the model.

Capital Investment

In the current analysis a combination of the “capacity factored” and “equipment factored” estimate methods are used to approximate the direct bioethanol plant costs. The “equipment factored” estimate method calculates the cost by converting the cost of equipment to direct plant cost using a multiplication factor. In the “capacity factored” estimate method, capacity ratios are raised to an exponent. This method takes into consideration the effect of economies of scale on cost and can be applied at all levels, i.e. equipment or even at a plant level.

In the current analysis the "capacity factored" estimate method is applied to the major equipment of an ethanol plant. In order to estimate the cost of the major equipment of a new ethanol plant it utilises the ratio of the production capacity of a base ethanol plant to a new ethanol plant multiplied by the cost of the major equipment of the base ethanol plant. Additionally a scale-up factor was applied to the capacity ratio in order to adjust equipment costs for different sizes.

The **cost of the major equipment** of a new ethanol plant is estimated by using the following formula:

$$\frac{\sum C_{E2}}{\sum C_{E1}} = \left(\frac{S_2}{S_1}\right)^n$$

where: ΣC_{E1} = The known cost of major process equipment of an ethanol plant having corresponding size S_1, €

ΣC_{E2} = The approximate cost of major process equipment of an ethanol plant having size S_2, €

S_i = Size of ethanol facility, t EtOH/yr

n = Scale-up factor or capacity index, dimensionless

The base ethanol plant considered in the analysis with a production capacity of 35,000 ton ethanol per year and the cost of equipment is estimated at around 12,410,000 €. The scale-up factor was derived from vendors' quotes by applying data fitting methods and is equals to 0.61.

Once the cost of the major equipment is available, the "equipment factored" estimate method is applied to enable the calculation of the direct plant costs by multiplying the delivered cost of the major equipment by a factor. In the process industries, this factor is known as "Lang" multiplication factor. In the present analysis the "Lang" multiplication factor was taken equal to 2.8.

In order to convert the major equipment cost to **direct plant costs** the following formula is applied:

Direct plant costs = 2.8 × Delivered cost of the major equipment

Once the direct plant costs have been calculated, the **indirect plant costs** are computed e.g. engineering costs and construction expenses. The components of the indirect plant costs are estimated as a percentage of direct plant costs. In this particular analysis, engineering and construction expenses are considered 5% and 2% of direct plant costs, respectively. Hence, indirect plant cost we get:

Indirect plant cost = 0.07 × Direct plant costs

In order to arrive at the **capital costs**, the contingency component is added to the sum of direct and indirect plant costs. The contingency component is the sum of 5% of direct and indirect plant costs.

Capital cost = (1.05 × Direct plant costs) + (0.05 × Indirect plant cost)

To obtain the **compounded capital costs,** the interest expenses incurred during the construction period, on the drawdown of the available credit line, is added to the capital costs of the plant.

Compounded capital costs = Capital costs + Interest during construction

The **total capital investment** is obtained by adding start-up costs to the compounded capital costs. Start-up costs are capitalised as organisational expenses. Start-up cost is considered as 5% of capital cost.

Total capital investment = Compounded capital costs + (0.05 × Capital costs)

Allowable range of capacities vary from 10000 to 120000 t. Capital costs are shown in Figure 5.1, illustrating a decreasing rate of increase of capital costs with increasing scale. This means decreasing average capital costs are associated with larger ethanol plants.

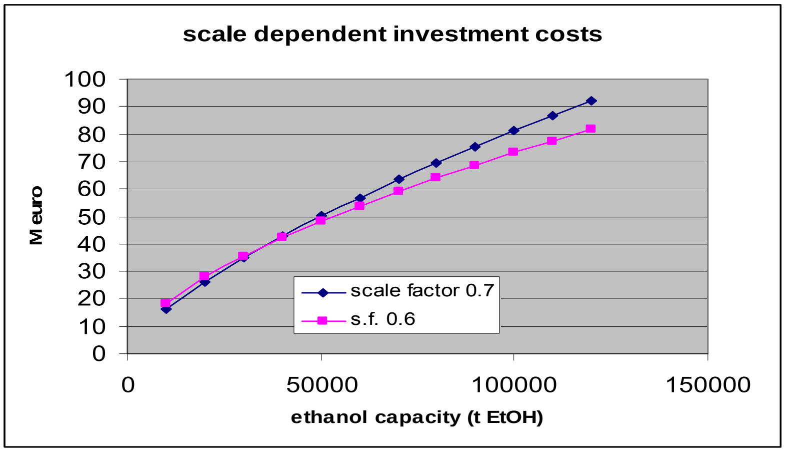


Figure 5.1. Investment cost of ethanol plant

Requirement and cost of personnel

Plant personnel include plant manager, production manager, lab manager, shift supervisor, maintenance supervisor, operators, maintenance technicians, lab technicians, shipping/receiving clerks, etc. Administrative personnel include general manager, marketing manager, accountant, secretary, receptionist, etc.

The module uses the following scale relationships in order to calculate personnel requirements given that the size of the ethanol plant is between 10,000 ton per year and 120,000 ton per year:

$$P_{tot} = 12.102381 + 0.1358788 * (S_{EtOH\ plant})^{0.49} \qquad (9)$$

$$P_{adm} = -21.91331 + 17.62626 * (S_{EtOH\ plant})^{0.05} \qquad (10)$$

Where: $S_{EtOH\ plant}$ = *Ethanol plant capacity, t EtOH/year*

P_{tot} = *Total personnel*

P_{adm} = *Administrative personnel*

The operating personnel, (P_{oper}), is calculated by subtracting administrative personnel from total personnel, ($P_{oper} = P_{tot} - P_{adm}$).

Monthly cost is the one twelfth of average annual wage for operating and administrative personnel as well. Monthly cost of personnel is given in Table 5.6.

Table 5.6 Personnel requirement and cost of personnel for bioethanol plant

Personnel categories	Monthly cost Euro/employee	Number of employee		Total monthly cost (Euro)	
		Wheat based plant	Sugar beet based plant	Wheat based plant	Sugar beet based plant
Operating	1,500	38	27	57,000	40,500
Administrative	2,800	9	8	25,200	22,400
Total		**47**	**35**	**82,200**	**62,900**

Cost of feedstock

The sugar beet and the wheat grain are the two main raw material of the ethanol production unit, procure from the farmers who want to achieve maximum profit from selling. On the other hand, the industry wants to buy the raw materials with minimum possible cost. The market price of raw materials for bioethanol will be such that it satisfies the farmers to supply required amount of feedstock for the industry. Price of feedstock wheat and sugar beet is estimated 140€/t and 31.28€/t respectively. Cost of feedstock is presented in the Table 5.7.

Table 5.7 Cost of feedstock per ton of ethanol

Feedstock	Specific consumption (t/t EtOH)	Price (€/t)	Cost (€/t EtOH)
Wheat	3.34	140	468.15
Sugar beet	14.94	31.28	467.35

Cost of chemicals and other materials

In the production process of ethanol from wheat and sugar beet involved a series of auxiliary materials. The auxiliary materials includes various chemical substances, yeast and fresh water. The chemical substances are use to regulate pH, to provide nutrition to yeast, to reduce foam, cleaning, etc. Some of these substances are common in the production of bioethanol both from wheat and sugar beet but in different quantities. Much of the water used in the ethanol plant is recycled back into the process. There are, however, certain areas where fresh water is needed. Those areas include boiler makeup water and cooling tower water. A fresh water requirement for an ethanol plant is considered proportional to ethanol production. The auxiliary materials as well as the required quantities and their costs is shown in Table 5.8.

Cost of electric energy and steam

Requirement of electricity and steam in the ethanol production process depends on the type of feedstock. Steam is produced by using fuel oil. To produce one ton of steam, 0.072 ton of fuel oil is required. In case of ethanol production from wheat, 5 tons of steam is required for the production of one ton ethanol. On the other hand, 4.42 tons of steam is required for the production of one ton of ethanol from sugar beet. However, 5×0.072 = 0.36 ton of fuel oil is required for steam for the production of 1 ton ethanol from wheat and 4.42×0.072 = 0.32 ton of fuel oil for steam is required for the production of 1 ton ethanol from sugar beet. Cost of electric energy and steam is presented in Table 5.9.

Table 5.8 Required quantities and cost of auxiliary materials for the production of 1 ton ethanol.

Item	Required quantity (kg/t EtOH)		Cost (€/t EtOH)	
	Wheat	Sugar beet	Wheat	Sugar beet
Caustic soda	44.00	-	16.28	
Sulphuric acid	19.00	11.35	1.9	1.14
Calcium chloride	2.50	-	0.78	-
Diammonium phosphate	3.80	-	3.04	-
Antifoaming agent (oil)	0,10	2.04	0.24	4.90
A-Amylase	1.40	-	6.16	-
Gluco-Amylase	2.00	-	8.80	-
Yeast	0.70	0.70	4.20	4.20
Make-up water (m^3)	6.20	8.60	5.77	8.00
Phosphoric acid	-	0.36	-	0.29
NaOH	-	2.39	-	0.88
Urea	-	0.45	-	0.13
Total			**47.17**	**19.53**

Table 5.9 Required quantities and cost of electric energy and steam for the production of 1 ton ethanol.

Item	Unit	Required amount (Unit/t EtOH)		Cost (€/t EtOH)	
		Wheat	Sugar beet	Wheat	Sugar beet
Electricity	kWh	503	228.7	30.18	13.72
Steam	t	5	4.42	180.00	159.12

Miscellaneous operating and general expenses

Operating expenses

Operating expenses includes maintenance/repair cost, operating supplies, laboratory charges, cost of insurance, plant overhead cost, rent cost etc. Maintenance cost includes the equipment and supplies necessary for keeping the plant equipment in efficient operating condition. It is estimated as a percentage of the capital costs. Current value is assumed equal to 1.5% of capital costs. Operating supplies and laboratory charges includes miscellaneous supplies that are needed to keep the process functioning efficiently and the cost of laboratory tests for operations and product-quality control. On annual basis operating supplies and laboratory charges are estimated as a percentage of maintenance cost and operating labour costs, respectively. cost of *Insurance is calculated o*n annual basis. Insurance amounts to a percentage of capital costs. Current value is assumed equal to 0.75% of capital costs. Rent includes all costs for rented land and buildings, if any. On annual basis it is defined as a percentage of value of rented land and buildings. In this particular case, rent cost is not included as because the land and buildings are readily available. Plant overhead costs includes all the expenditures required for routine plant services, e.g. general plant maintenance, safety and protection, lighting, interplant communications and transportation, employment offices, etc. Overhead costs are estimated, on annual basis, as a percentage of annual operating labour costs. Explicitly,

Maintenance/repair cost = 0.015 × Capital cost

Operating supplies cost = 0.10 × Maintenance/repair cost

Laboratory charges = 0.05 × Operating labour cost

Insurance cost = 0.0075 × Total capital cost

Plant overhead cost = 0.50 × Operating labour cost

Administrative and marketing expenses

Administrative and marketing expenses includes the expenses which are connected with the administrative and marketing activities e.g. professional services, office supplies, outside communications, travel, advertising, etc. They are estimated, on annual basis, as a percentage of annual administrative labour costs or of sales. The costs considered in this study are:

Professional services (legal, accounting, etc.) = 0.10 × Administrative labour cost
Office supplies = 0.025 × Administrative labour cost
Water and electricity = 0.025 × Administrative labour cost
Communication = 0.05 × Administrative labour cost
Travel = 0.10 × Administrative labour cost

5.5.3 Integrated Model

As mentioned before, a mathematical programming model for industry is developed for the finding of optimal economic size of bioethanol plant, which ties together with the agricultural sector model. The industrial model is build in such a way that does not run autonomously, it required results and equations from agricultural model that described in the previous section. The agricultural sector model and the industrial model are integrated so as to the models are jointly exploited the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply to maximize total economic surplus. For the development of industrial model, the LIBEM-bioethanol model is used from where the necessary elements of technical and economic equation were drawn.

The objective function of the integrated model that concerns the maximization of total profit is expressed by the following relation:

$$\max_{x^f} \sum_{cp} \left(\left(p_{cp}^f + s_{cp} \right) y_{cp}^f + sub_{cp} - v_{cp}^f \right) x_{cp}^f + \sum_{ce} \left(\left(a_{ce} - \frac{b_{ce}}{2} \sum_f w_f y_{ce}^f x_{ce}^f \right) y_{ce}^f - v_{ce}^f \right) x_{ce}^f + p_{eth} * q_{eth}$$
$$+ p_{ddgs} * q_{ddgs} + p_{plp} * q_{plp} - tc_{ind}$$

Where p_{eth} and q_{eth} stands for price and quantity of ethanol production (t) per year, p_{ddgs} and q_{ddgs} represents price and quantity of by-product DDGS, and p_{plp} and q_{plp} represents price and quantity of by-product pulp produced in a year, respectively. The tc_{ind} indicates total annual cost of the industry.

5.5.4. GHG emission in the Modelling

GHG emission in the bioethanol production system is incorporated in the model to examine environmental performance of biofuel production system. Emission of different greenhouse gases is estimated on the basis of kilograms of carbon dioxide equivalent (CO_2e) using lifecycle emission factor. CO_2 emission in biomass production, transportation as well as in the industrial processing is incorporated in the model. GHG potential is examined by net CO_2 emission in the bioethanol production and combustion. CO_2 emission in the agricultural sector is examined how the emission changed with the introduction of energy crops in the cropping mix. On the other hand, CO_2 emission by the amount of fossil fuel that can be avoided by replacing with ethanol is also taken into consideration. The net CO_2 emission that we wish to be minimum can be express as:

$$CO_{2eth\_agri} + CO_{2trans} + CO_{2ind} - CO_{2gasoline}$$

Where CO_{2eth_agri} represents net CO_2 emission in the agricultural sector for biomass production, CO_{2trans} represents CO_2 emission in the transportation, CO_{2ind} expresses CO_2 emission in the industrial processing and $CO_{2gasoline}$ represents the potential amount of CO_2 emission by the amount of gasoline used that will be avoided by replacing with ethanol.

5.5.5. Modelling with biogas plant facilities

A second configuration of ethanol plant with biogas plant is considered to evaluate alternative economic and environmental performance of bioethanol activity. The integrated agro-industrial model is modified and incorporated biogas facility. A co-generation unit is also considered with biogas unit so that electricity requirement for ethanol plant can be met by electricity generated by the biogas plant. The biogas unit is configured for using DDGS and pulp as raw material, by-product from ethanol production. CO_2 emission during the industrial processing that is the biggest part of total emission in ethanol production system is examined. Moreover, CO_2 credit from electricity sale is added to this configuration.

5.5.5.1 Determination of biogas plant size

Raw material for biogas production for the proposed biogas plant is by product from ethanol plant. Beet pulp during ethanol production with sugar beet and DDGS during ethanol production from wheat will be used as feedstock for biogas plant. The biogas plant size will be determined by the amount of beet pulp and DDGS produced as by-product in the ethanol production process. Ethanol plant operational period for Thessaly sugar plant is considered 330 days per year. Ethanol production from sugar beet is a seasonal operational activity because sugar beet is degraded very fast by micro-organism and cannot be stored. Generally sugar beet harvesting is started from September and the factory may run with it for roughly 100 days. For the remaining 230 days, the factory will run with wheat feedstock that can be stored and be used for any time period. Taking into consideration this factor biogas equipment can be used in two seasons working mode. During sugar beet operational period biogas plant recycles beet pulp and molasses and the rest of time it will recycle silage, by-product from ethanol production from wheat.

In this study, the model suggested 120000 ton ethanol plant capacity per year to maximize total surplus. The ethanol plant is configured as the daily ethanol production will remain the same for each day regardless of what feedstock is used. Proportion of feedstock for ethanol production is rationalized by the following relationship:

Quantity of ethanol from wheat/230 = Quantity of ethanol from sugar beet/100

According to the above mentioned ratio, for 120000 ton ethanol capacity, 83636 ton ethanol from wheat and 36364 ton ethanol from sugar beet would be produced per year. Hence, the daily ethanol production capacity either from wheat or from sugar beet is 363.64 ton (83636/230 = 36364/100 = 363.64).

The transformation ratio of ethanol from wheat is 0.299 and rate of silage/DDGS production (wheat to silage/DDGS) as by-product from wheat based ethanol production is 0.32. Hence, silage production from wheat based ethanol production process is (363.64/0.299)×0.32 = 389 ton silage/DDGS per day. On the other hand, transformation ratio of ethanol from sugar beet is 0.067 and rate of pulp production (beet to pulp) as by-product from sugar beet based ethanol production is 0.2. Hence, pulp production from sugar beet based ethanol production process is (363.64/0.067)×0.2 = 1085.5 ton pulp per day.

Considering daily by-product production (silage from wheat is 389 ton per day and pulp from sugar beet is 1085.5 ton per day), biogas plant size is determined 400 ton raw material capacity per day. During ethanol production from wheat, whole by-product (silage) will be utilized in biogas production. Remaining amount of beet pulp (1085.5 – 400 = 685.5 ton per day) during ethanol production from sugar beet can be sold directly.

5.5.5.2 Determination of co-generation capacity

Co-generation capacity is determined on the basis of biogas production that can be used energy sources for cogeneration unit. According to (ZORG, 2010), 72000 m^3/day biogas will be produce from 400 ton per day raw material capacity biogas plant that can run (72000/24)×2.6=7800 kW capacity co-generation unit. Electricity requirement for ethanol plant during wheat based processing is 7621 kW and during sugar beet based processing is 3465 kW for optimal ethanol plant capacity of 363.64 ton ethanol per day (or 120 kt ethanol per year). Considering biogas production potentiality and electricity requirement for ethanol plant, 7650 kW electricity generating co-generation unit is determined for the proposed biogas plant.

5.5.5.3 Estimation of biogas plant cost (with co-generation unit)

For the ethanol production plant, 35000 ton ethanol production per year is considered as base plant capacity. Capital cost for base capacity is estimated and then to estimate current capacity, scale factor is used. During the operational period of 330 days in a year, for the base capacity of 35000 ton, 106 (=35000/330) ton of ethanol production capacity per day is considered. At the base ethanol plant capacity, 113.5 (=(106/0.299)×0.32) ton silage per day for the wheat based processing and 316.5 (=(106/0.067)×0.2) ton pulp per day for sugar beet based processing is produced. Hence, 120 ton raw material capacity per day that corresponds to the base capacity of ethanol production plant is considered as base biogas plant capacity.

The basis of cost estimation for biogas plant and co-generation unit is taken from ZORG biogas (ZORG, 2010). Upon determination of cost for base plant capacity, scale factor is used to estimate cost for current capacity by the following relationship:

$$\text{Cost for current capacity} = (\text{current capacity}/\text{base capacity})^{\text{scale factor}} \times \text{base capacity cost}$$

For this study, the base capacity is considered 120 ton raw material per day, current capacity is 400 ton raw material per day, base capacity cost with co-generation unit is estimated 4045602 Euro and the scale factor is considered 0.61.

The estimated capital cost with co-generation unit for current capacity of 400 ton raw material per day is,

$$(400/120)^{0.61} \times 4045602 = 8{,}432{,}167 \text{ Euro}$$

CHAPTER VI: CASE STUDY OF ETHANOL PLANT IN THESSALY

6.1 Introduction

To create opportunities for sustainable management of the existing sugar industry infrastructure in Greece under recent reforms in the Common Agricultural Policy, we have stimulated our interest to evaluate possibility of matching the sugar sector with bio-ethanol production. This may help to achieve bio-fuel policy targets and reduce net GHG emission also. In the present study, a micro-economic model of supply chains that includes an agricultural sector model has been developed for this purpose. This latter is supplemented by an industry model of biofuel chains (bioethanol from wheat and sugar beet), and by the demand scheme for products and by-products model in a way that a partial equilibrium model has been formulated. LC analysis results is integrated so that to form an LCAA model. A micro-economic analysis of biofuel activity is carried out in order to estimate agents' surpluses. The deadweight loss of the activity is calculated against the environmental benefits of reductions in the emissions of greenhouse gases.

6.2 Agricultural Sector

Energy crops for ethanol considered are sugar beet and secondly wheat is cultivated mainly in two types of arable crop farms: sugar-beet producing exploitations and cotton oriented exploitations. Farm Accounting Data Network (FADN) data on number of farms per type, surfaces cultivated, and land set aside concerning the above farm types have been used in this exercise along with detailed data on inputs of arable crops used by each farm.

It is assumed that farms holding sugar-beet quota and possessing considerable experience on its cultivation (since they had multi-year contracts with the sugar industry) will be the first and presumably most efficient suppliers of the ethanol plant with beet. The reason for choosing cotton cultivating farms beside sugar-beet is that an enormous number of farms cultivate this staple crop in the region. In order to ensure profitability for the ethanol plant it is important to spread capital and administrative charges over a longer period. It points out to the attractiveness of using mixed crops, in this case beet and grains, to extend the processing season that can thus count 330 days per year. The cultivation of irrigated wheat is considered to supply ethanol plant by grains, first because output is much higher than that of non-irrigated wheat, soft or hard, and secondly because it means extensive cotton cultivation replacing monoculture with cotton-wheat rotation (Rozakis et al., 2001). CO_2 emission in agricultural sector is calculated by the amount of energy for fuel, fertilizer and chemicals used.

6.2.1 Description of Sample

In the present study we use data on farm structure, costs and yields from 2001-2002, i.e., under the CAP is considered (scenario 1) then changes of CAP, i.e., new CAP element like decoupling of aid and cross compliance are introduced in the model (scenario 2). Farms which cultivated at least one stremma (one tenth of a hectare) of cotton or at least one with sugar beet for the farming period 2001-2002 were selected for the study. A group of 344 arable farms out of all farms monitored by the FADN, representing in total 22,845 farms of the region is selected as sample. The reason of choosing cotton producing farm is the soil for cotton cultivation. The cotton belongs to irrigatd crop, i.e., the crops need water to produce. This soil therefore is suitable to cultivate irrigated wheat, by any chance replacing previous cotton cultivation. The cotton cultivation moreover becomes questioned on the basis of new CAP and somebody may find more interesting to cultivate irrigated wheat. The reason of particular interest in irrigated wheat is its output is higher enough than soft or dry wheat. With this way, the factory can get required quantity of grain with minimum acreage.

It has been mentioned that the bioethanol plant is located in Larissa thus the feedstock wheat and sugar beet will be supplied from prefecture around the region. The selected sample agricultural farm comes from the prefecture of Thessaly, namely, the prefecture Larissa, Karditsa, Magnesia and Trikala as well as the prefecture Fthiotida. According to the FADN, the four prefectures of Thessaly belong in a wider region with the name Region 470, while the prefecture Fthiotida belongs in Region 480. The structural differences of sample agricultural farms are presented analytically in the Table 6.1. As appears from the table, the prefecture Karditsa has a very high percentage in irrigated land (87%) that might be interesting to cultivate irrigated wheat.

Table 6.1 Structural differences of sample farms

Prefecture	Farms in sample	Represented farms	Average acreage (farm size) (ha)	Total represented acreage (ha)	Irrigated land (%)
Karditsa	119	8511	11.49	87089	87
Larisa	146	8142	18.3	122371	67
Magnisia	18	1203	20	21692	48
Trikala	53	4260	7.22	24664	83
Fthiotida	8	729	15.86	9235	63
Total/weighted average	344	22845	14.27	265051	73

Crops cultivated by those farms are: Soft wheat, Hard wheat, Irrigated wheat, Maize, Tobacco, Cotton, Dry cotton, Sugar beet, Tomato, Potato, Alfalfa, feedstock maize and intercropped vetch to conform with the cross compliance term of the new CAP. A picture of cultivated acreage of each crop in different prefecture in 2002 is shown in Table 6.2. With regards to acreage, cotton appears to dominate followed by durum wheat. With regards to sugar beet, overwhelming concentration is appears in the prefecture of Larissa while it completely absent in prefecture Ftiotida.

Table 6.2 Cropping mix (acreage) of sample farmers in the region (ha)

Prefecture	Crops									
	sfw	drw	mze	tob	cot	pot	sbt	tom	mzf	alf
Karditsa	2.01	87.52	37.20	16.49	680.53	0	17.80	2.83	0	17.85
Larissa	0.85	310.48	56.64	1.19	714.96	1.24	93.34	1.81	2.24	25.05
Magnisia	0	107.99	3.86	0	84.14	0	11.02	0.91	0	8.98
Trikala	1.09	14.40	51.36	0.64	157.32	0	5.89	0	1.43	7.11
Fthiotida	0	22.04	8.16	10.058	35.21	0	0	0	0	9.95
Total	3.96	542.44	157.23	28.39	1672.17	1.24	128.06	5.56	3.67	68.95

Data used for the particular crop and for each agricultural sample farm were: yield (kg/ha), prices (€), subsidy (€/kg and €/ha depending on the type of crop) and the variable costs (€/ha). Yield variation in different prefecture for the main crops in Thessaly is presented in Table 6.3. Variable cost includes: Seeds and seedlings purchased, fertilizers and soil amelioratives, protection chemicals, fuels and lubricants, electrical energy, water, running maintenance of equipment, maintenance of buildings and landed improvements, salaries and social taxes, and wages of hired labour. Average variable cost of main crops in different prefecture of Thessaly is shown in Table 6.4

Table 6.3 Yield variation in different prefecture for the main crops of Thessaly (kg/ha)

Prefecture	Crops									
	s.wheat	d.wheat	maize	tobacc	cotton	potato	s.beet	tomato	mzf	alfalfa
Karditsa	3632.5	4106.5	10489	3131.9	3529.5	na	73523	60607	na	16937
Larissa	2930	3515.5	12699	3383.3	3820	27500	69625	46665	60000	38758
Magnisia	na	3429.3	14000	na	4147.5	na	73571	75000	na	17050
Trikala	3960	3885	12373	3800	3455.9	na	74487	na	62350	13681
Fthiotida	na	2672.5	10030	3150	3408.8	na	na	na	na	10500
Total	3538.75	3671.63	11834	3207.9	3664.8	27500	70976	60736	61175	25364

Table 6.4 Average variable cost of main crops in different prefecture of Thessaly (€/ha)

Prefecture	Crops								
	s.wheat	d.wheat	maize	tobacco	cotton	s.beet	tomato	mzf	alfalfa
Karditsa	316.78	326.13	944.99	1572.84	812.94	1325.32	2021.4	964	1182.6
Larissa	319.13	356.7	930.21	1564.41	837.76	1338.56	2026.29	964	1166.68
Magnisia	318	353.93	964	1572	813.39	1288.09	2001.11	964	1180
Trikala	315.33	325.83	923.13	1572	775.9	1291.44	2030	960.96	1154.76
Fthiotida	318	275.4	857.33	1695.33	639.75	1306	2030	964	985
Total	317.61	342.29	934.34	1571.69	813.45	1325.49	2023.66	963.48	1169.1

6.2.2 Model validation

The arable sector model is validated by comparing farming plan of the observation year 2002 which is considered as the base year with the farming plan from the model outcome. The farming plan proposes by the model is considered as the optimum farming plan for each agricultural farm to maximize their gross margin. To evaluate the proximity of the LP solution, the following distance measure is used:

$$M_1^{opt}\left(x^{opt}\right) = \frac{L_1\left(x^{opt}, x^{obs}\right)}{TotalLand} = \frac{\sum_c \left|x_c^{opt} - x_c^{obs}\right|}{\sum_{ci} x_c^{obs}}$$

Where: x_c^{opt}: the cultivated area of each crop c in acres with base optimum farming plan (model)

x_c^{obs} : the cultivated area in acres of each crop c with base observed farming plan (observed)

The deviations between observations and model results counterbalances with absolute difference between two values of the total observed acreage. The value of deviation is desirable to be small as long as possible. Base year (2002) observed and optimal crop mix is shown in table 6.5 and deviation results are shown in Table 6.6.

Table 6.5 Observed and optimal crop mix for 2002 (ha)

	sfw	drw	mze	tob	cot	pot	sbt	tom	mzf	alf
Observed 2002	3.965	542.439	157.233	28.394	1672.173	1.238	128.06	5.56	3.669	68.947
Optimal 2002	1.941	569.931	204.48	28.394	1657.272	0.776	94.771	4.126	0	48.804

Table 6.6 Deviations between observations 2002 and optimization 2002

Deviation	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8
Frequency	258	28	18	15	6	8	4	4	2	1
Cumulative frequency	258	286	304	319	325	333	337	341	343	344
% of frequency	75.0%	83.1%	88.4%	92.7%	94.5%	96.8%	98.0%	99.1%	99.7%	100%

It is observed from the above table that the deviation from the above relation (in other words, the distance between the two solutions using a L_1 metric) varies from 0 to 1.62 while the mean of deviation is 0.12. It is also observed that 258 out of 244, i.e., 75% sample farm's deviation is zero and 97% sample farm fall in the deviation of 1. The deviation is even small when we do not examine each farm separately. When we consider the sample as a whole the total deviation is equal to just 0.06.

The overall model fit is illustrated in figure 6.1. One can observe surfaces cultivated at the regional level by main crops in the base year 2002 as well as the optimal cropping plan for scenario 1 (CAP 2000). Model optimal results approach closely to observed surfaces forming a validation test proving the selected model specification can be used to perform predictions of the farmers' behavior under different parameters' sets. A national model of similar structure (Rozakis et al., 2008b) passed successfully the validation test that increases confidence on non-linear sector models of Greek arable cropping systems. As a matter of fact, in the optimal solution when the model runs under the CAP 2003 regime (scenario 2) cotton cultivation is significantly decreased, replaced by maize, alfalfa and soft wheat. Also sugar beet almost disappears due to drastic price reductions.

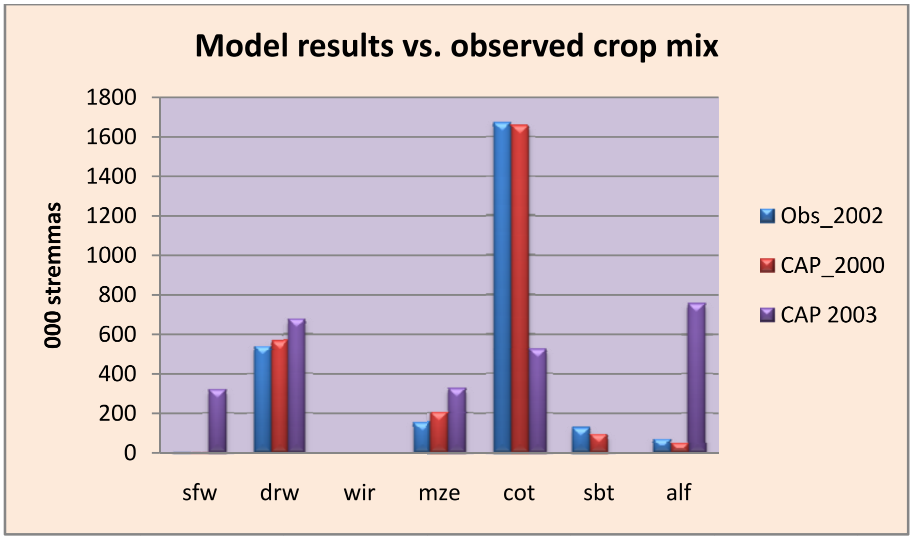


Figure 6.1 Observed and optimal crop surfaces at the regional level

6.3 Industry Sector

Technical and economic data for the production process of ethanol and determination of various costs for the industry model are drilled by (Soldatos and Kallivroussis, 2001) adapted to the conditions of ex-sugar factory in Thessaly by (Maki, 2007). Data include a transformation ratio from wheat and sugar beet to ethanol, corresponding prices and required quantities (per produced quantity of ethanol) of additional and auxiliary matters e.g. chemical substances, the requirements in electrical energy and steam and the corresponding costs, production rate of by-products, the sale prices of produced ethanol and by-products.

6.3.1 Current state of the plant

The Larissa sugar factory that already seized its production and considering to produce bioethanol, is located in Larissa, two kilometers from Larissa – Sikuriou provincial road and Larissa-Thessaloniki old National Road. It was built in a private plot of 32.4 ha and operated since 1961 (Maki, 2007).

Sugar beet was the raw material of sugar production for the factory that comes mainly from the region of Thessaly, which is the largest beet area of Greece. The campaign works starts in early August, lasts about 100 days. After continuous extension of the factory, the current treatment capacity of beet is 8,000 t/24 hr and is capable of producing 70,000 ton of sugar per year. The permanent workforce is 182 persons (Maki, 2007).

6.3.2 Existing facilities and equipment

Sugar production is a complex process, involving a large number of processing steps and required several machineries. The main steps and existing machineries for those steps of sugar production in the Larissa sugar factory are presented in figure 6.2.

Weighing-collection unloading of sugar beet	Washing	Extraction	Cleaning	Condensation	Crystallization Centrifuging of sugar
Sugar beet transported at factory by road, and in some cases rail Weigh and assess the level of impurities and sugar	Pass through liquid transport channels with a pump "mammoth" led to washing After washing the beets are cut into thin pieces in cutting machines and devices promote the extraction	Sliced beet conveyed against counter path of hot water The raw juice produced contains about 97% of sugar from beet. The extracted particles after pressing and drying are used for animal feed.	Lime and CO_2 are added to the juice to bond with non-sugar compounds The calcium carbonate precipitate containing the bound debris deposited in the filters, resulting clear sugar juice.	The thin juice is send to a series of successive evaporation containers to remove water, the sugar is desolved. The thick juice obtained after the evaporation, concentrate more on devices that operate in a vacuum until crystal formation	The crystals grow and show a mixture of crystals and syrup, the zacharomaza. The thick juice contains 60% sugar. The zacharomaza cooled and the influence of centrifugal force, the white granulated sugar is separated from the syrup. It is washed with hot water and white sugar, dried and stored

Figure 6.2 Main steps and existing machineries of sugar production in the Larissa sugar factory

6.3.3 Additional requirement for conversion to ethanol production in Larissa sugar plant

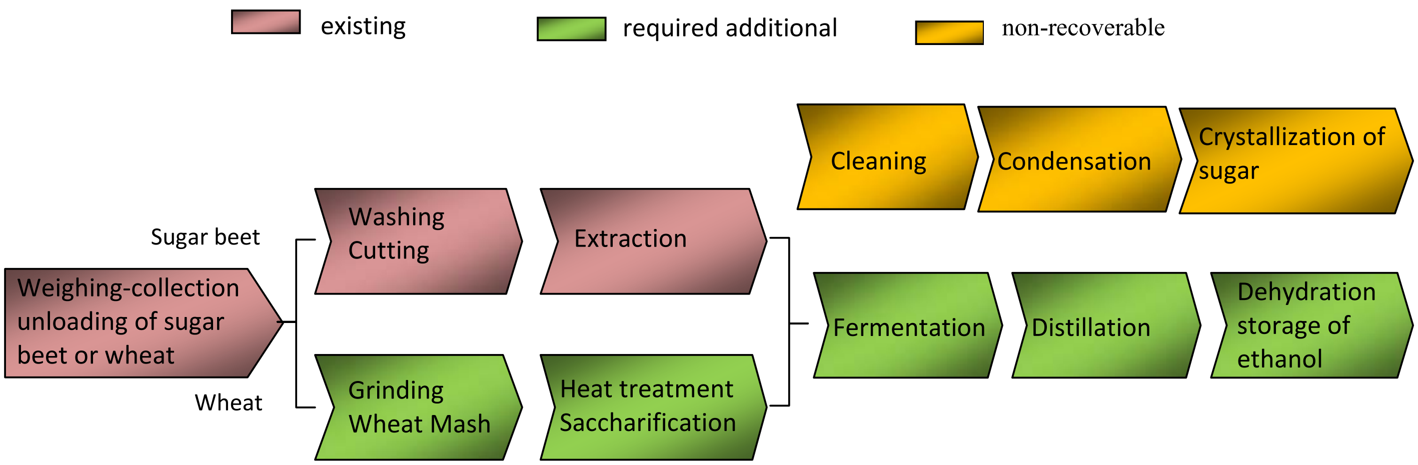
Conversion of a sugar plant to an ethanol producing plant obviously needs some modification and addition to existing facilities and equipment. Moreover ethanol production process from sugar beet and from wheat grain varies. Additional activities and equipment required for production of ethanol from sugar beet includes: fermentation, distillation, dehydration, recovery, storage, instrumentation, quality control, shipment of ethanol. On the other hand ethanol production from wheat required additional process and equipment like: grinding of grain, pulping, starch hydrolysis and saccharification with enzymes.

Diagrammatic depiction of essential modifications as well as additions in the existing installations and the equipment is shown in figure 6.3 (Maki, 2007).

6.3.4 Additional requirement for biogas plant

A biogas plant provision from leftover residue is considered to generate autonomous electricity and heat for the industrial process. Pulp is the most important by-product of sugar beet conversion process. It can be added to an anaerobic digester to produce biogas (Malca and Freire, 2006). On the other hand, DDGS from fermentation process in the ethanol production from wheat can also be utilized for biogas production.

Biogas plant consists of constructed facilities and equipment. Constructed facilities includes digester, open tank for digested biomass, technical building. Main equipment includes mixing equipment, substrate separation unit, gas conditioning unit, heat supply station, automatics, electric equipment, air supply system, gas holder, substrate feeding system, co-generator for electricity generation.



Existing facilities are used to receive feedstock.

Some modification to conveyor system may be required for wheat

The wheat grain is ground and pulped with water

The pulp is heated and mixed with enzymes and starch is broken down into complex sugars.

The compound is cooled, mixed with new enzymes and pH adjusted to create simple sugars

Sugar beet and wheat must be treated in different periods if both are used as feedstock

Yeast is added and feeds on sugars to produce alcohol and CO2

Ethanol is distilled from the beer in a series of successive distillation column at a concentration of 96% concentrat.

The residue is recovered and dried for animal feed

The remaining water is removed with molecular sieves

The ethanol is cooled and stored before distribution

Figure 6.3 Diagram showing the necessary amendments and additions to existing facilities and equipment

CHAPTER VII: RISK ANALYSIS

7.1 Introduction

Uncertainty in exogenous parameters is examined in this chapter. Uncertain environment in competitive markets of products and by-products of bioethanol is considered. The petroleum price for example is considered exogenous to the partial equilibrium model, we need to take it into consideration in order to measure effects to profitability of variations of cost items and price of the biofuel activities. For this purpose the Monte Carlo simulation method can be used to analyze uncertainty and expected outcome in changing conditions.

7.2 The Monte Carlo Simulation

Monte Carlo simulation is a technique that converts uncertainties in input variables of a model into probability distributions. By combining the distributions and randomly selecting values from them, it recalculates the simulated model many times and brings out the probability of the output (Iordanova, 2011).

Basic characteristics of the Monte Carlo simulation:

- It allows several inputs to be used at the same time to create the probability distribution of one or more outputs.
- Different types of probability distributions can be assigned to the inputs of the model. When the distribution is unknown, the one that represents the best fit could be chosen.
- The use of random numbers characterizes Monte Carlo simulation as a stochastic method. The random numbers have to be independent; no correlation should exist between them.
- Monte Carlo simulation generates the output as a range instead of a fixed value and shows how likely the output value is to occur in the range.

This method consists in simultaneously varying model parameters and then running the model for each discrete set of parameters in search of the model variable values. The set of values related to selected variables resulted by a sufficient number of model optimisations gives us their frequency distribution. This approach differs from a simple sensitivity analysis as it allows for visualizing variations and extreme values of model results depending on stochastic parameters, for simultaneous variation of all the critical model parameters (Rozakis and Sourie, 2005).

The principle of Monte Carlo sampling is based on the frequency interpretation of probability and requires a steady stream of random numbers. For continuous distributions we generate random numbers using the inverse transformation method. This method requires a cumulative distribution function (cdf) $f(x)$ in closed form and consists of giving to $f(x)$ a random value and to solve for x. Data from the simulation can be analysed using a terminating simulation approach. We make n independent replications of the model using the same initial conditions but running each replication with a different sequence of random numbers. If the measure of performance is represented by the variable X, this approach gives us the estimators X_1....., X_n from the n replications (Winston, 1991). These estimators are used to develop a 100 (1-a) percent confidence interval as follows:

$$\bar{X}(n) \pm t_{(n-1,\frac{a}{2})} \sqrt{S^2(n)/n}$$

For a fixed value of n, it returns the confidence interval for a population mean. The confidence interval is a range on either side of a sample mean.

7.3 Effect of price change

Price of food crop and raw material of ethanol production and prices of gasoline is the key factor that influences bioethanol competitiveness and sustainability. Food crop compete with energy crop that influence raw material supply and cost. On the other hand petroleum price influence production cost of bioethanol as well as competitiveness in the fuel market. The petroleum price is considered exogenous to the partial equilibrium model. In order to measure effects to profitability of variations of cost items and price of the biofuel activities price change of petroleum need to take into consideration.

World petroleum supply is controlled by few oil exporting countries. Price change of petroleum is influenced mostly by global socio political factor. Gasoline price and price volatility in 2010 is presented in Annexure VII. Price variation Average gasoline price (premium unleaded 10ppm fob) in 2010 was 607.6 Euro per ton where average minimum price was 581.6 and average maximum price was 634.2 Euro. Monthly minimum price varied from 534.4 euro to 667.3 Euro and maximum price varied from 591.9 Euro to 711.9 Euro per ton. Average standard deviation of price volatility was 15.9 that was variable in different months from 11 to 40 Euro per ton.

It is observed that in general, gasoline price are fluctuating day by day. In order to measure to profitability and sustainability of bioethanol production activity, future change and volatility in price of food, fuel as well as ethanol needs to take into consideration. Monte Carlo Simulation technique can be handily accommodated in the agro-industrial model to analyze uncertainty and expected outcome in changing conditions. This can be implemented by performing parametric optimization using LOOP command in GAMS as in the case of capacity determination. Neverthless, Monte Carlo simulation experiment requires at least several hundreds of iterations to get enough values for selected result items in order to estimate probability of occurance of extreme values and give meaningful answers. For this reason, parametric optimization has been implemented with regard to the supply of arable agricultural component of the integrated model using parallel computing. For details, the interested reader can see the paper in Annexure IX (Kremmydas et al., 2011) entitled "Enhancing Web-Spatial DSS Interactivity With Parallel Computing: The Case of Bio-energy Economic Assessment In Greece" to be presented in the BALCOR conference.

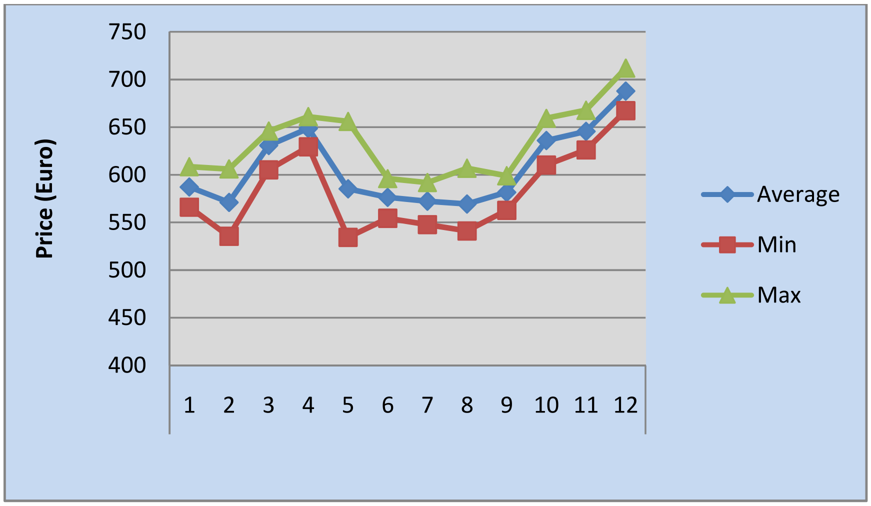


Figure 7.1: Gasoline price (premium unleaded 10ppm fob) volatility in 2010

CHAPTER VIII: RESULTS AND DISCUSSION

8.1 Introduction

Parametric optimization of the integrated agro-industrial model determined the optimal crop mix for farmers as well as the best technology configuration for the industry and size of the plant. As expected, biomass costs increase and transformation costs decrease with capacity in any case. Biomass costs are endogenously given by the model (dual prices of supply > demand type constraints) resulting from changes in the crop mix to satisfy the increasing biomass demand from the industry. In figure 8.1, the evolution of optimal crop mix at the regional level for increasing ethanol plant sizes is presented, starting from the CAP 2003 optimal solution. Figure 8.1 illustrates results for capacities from 30 to 120 thousand tons of ethanol. All magnitudes are reported in average values per ton of ethanol. A second configuration of the model is adopted with own biogas plant. Biogas plant is configured such that by-product from ethanol plant (DDGS and pulp) can be used as raw material and a co-generation unit with biogas plant is also considered so that electricity requirement for ethanol plant can be met by the unit.

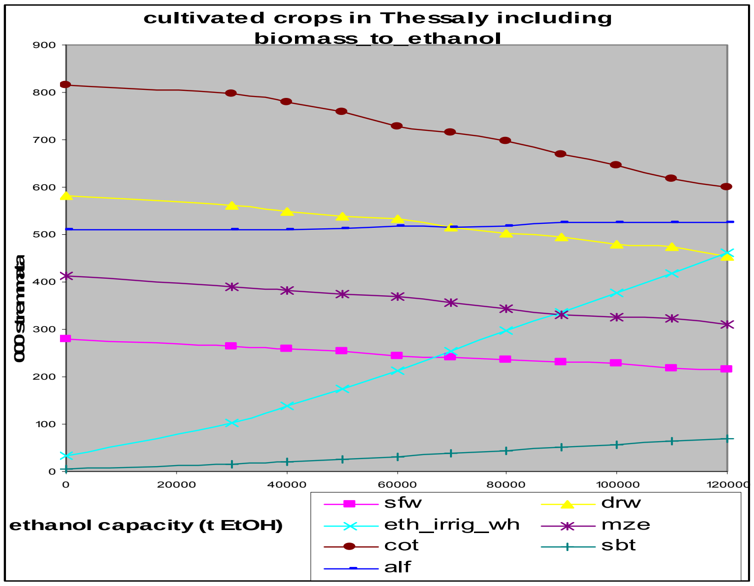


Figure 8.1. Evolution of cultivated surfaces by main food and energy crops.

8.2 Optimization in the agricultural sector

The agricultural sector model maximizes total gross margin determining optimal crop mix of the farm. Observed and optimal cultivated area per crop in different scenarios is presented in Table 8.1. Firstly the model is run given the CAP policy in force in year 2002 and compare with the observed area to verify the model reliability that has been discussed in chapter V. Then the constraints under new CAP are imposed on the model and run for different ethanol plant size. A new policy adopted in 2009 in Greek agriculture that coupled subsidy on cotton cultivation is 80 Euro per ha instead of 55 Euro per ha in 2003 new CAP reform. It is observed from the Table 8.1 that with the increase of plant size, irrigated wheat and sugar beet area is increasing but the other crops like soft wheat, durum wheat, maize cotton are decreasing. Tobacco, dry cotton and maize for fodder are disappeared and potato and tomato area remained unchanged, irrespective of plant size with subsidy on cotton cultivation at 55 Euro per ha. Alfalfa is slightly increasing due to cross compliance constraints included in the model. Under the policy of subsidy on cotton cultivation at the rate of 80 Euro per ha, cotton cultivation became competitive and cotton area increase substantially and soft cotton appears to be cultivated and wheat, maize, alfalfa area is decreased.

8.3 Optimization in industrial sector and optimal plant size

The industry sector model maximizes total profit of the industry but it combines agricultural sector model so that the model jointly maximize total welfare simultaneously (see in annex the mathematical specification of the integrated model). Input-output technical relations i.e., quantity of raw material used and total product and by-product production in the industry at optimal in different plant size are presented in Table 8.2. Key results of the model are presented in Figure 8.2. Detailed cost of production in different plant size and in different scenarios is presented in Appendix X. One can observe that raw material cost is the major part of total cost varying from 50-60% of it. With the increasing of plant size, raw material costs are increasing because of changes in crop mix to satisfy increasing biomass demand for the industry. That is more competitive crops are replaced and consequently opportunity cost of land dedicated to cultivate energy crops is increasing. On the other hand, capital cost per ton of ethanol is decreasing with the increase of plant size thank to applied economics of scale.

Table 8.1 Observed and optimal cultivated area per crop (00'ha) in different scenarios and in different ethanol plant size.

Scenarios		**Size(kt)**	**sau**	**sfw**	**drw**	**wir**	**maize**	**tob**	**cotd**	**cot**	**cots**	**potato**	**s.beet**	**tomato**	**mzf**	**alfalfa**	**vik**
Observed 2002		-	2643.5	3.9	542.4	0	157.2	28.3	31.9	1672.1	0	1.2	128.0	5.5	3.6	68.9	0
Opt 2002 (CAP 2000)		-	2642.3	1.9	569.9	0	204.4	28.3	31.9	1657.2	0	0.7	94.7	4.1	0	48.8	0
Nlp opt 2002(CAP2000)		-	2641.8	1.8	561.1	0.9	183.3	28.3	31.9	1655.4	0	0.7	86.1	4.1	0	87.8	0
Subsidy_cotton @55 €/h	NewCAP_no_ethanol	-	3029.4	284.3	593.8	0	422.8	0	0	826.4	0	1.2	0	4.1	0	510.7	385.8
	NewCAP with_ethanol	60	3027.9	244.6	534.3	213.9	368.3	0	0	728.6	0	1.2	31.2	4.1	0	517.1	384.3
	NewCAP with_ethanol	70	3028.1	242.0	515.5	254.8	355.8	0	0	715.8	0	1.2	37.5	4.1	0	516.5	384.5
	NewCAP with_ethanol	80	3027.8	235.3	502.3	296.4	343.7	0	0	698.3	0	1.2	44.1	4.1	0	517.8	384.2
	NewCAP with_ethanol	90	3025.9	229.7	493.7	337.0	330.1	0	0	670.3	0	1.2	50.6	4.1	0	526.4	382.4
	NewCAP with_ethanol	100	3025.9	228.3	479.0	377.0	325.3	0	0	645.0	0	1.2	56.8	4.1	0	526.4	382.4
	NewCAP with_ethanol	110	3026.2	217.7	473.2	418.4	323.2	0	0	616.9	0	1.2	63.4	4.1	0	525.0	382.7
	NewCAP with_ethanol	120	3025.9	216.1	453.9	462.2	310.2	0	0	599.2	0	1.2	69.7	4.1	0	526.5	382.3
NewCAP_sub_cot_80_no_eth		-	3056.9	178.9	353.6	0	160.9	0	0	1372.3	199.1	1.2	0	4.1	0	373.1	413.3
NewCAP_sub_cot_80_with_eth		120	3051.2	172.8	311.7	295.6	112.9	0	0	1191.8	108.4	1.2	43.8	4.1	0	400.8	407.6

Input cost like chemicals, steam and electric energy is constant per ton of ethanol because those are proportional to ethanol production but labour cost including administrative cost and other variable costs are decreasing resulting total cost is decreasing with the increase of plant size at smaller plant sizes. Minimum total cost per ton of ethanol production is found at the plant size of 50kt. Total cost at the 50kt plant size is 848 Euro per ton against the total sale (ethanol plus by-product) of 932 Euro per ton. The model maximizes total profit, thus it proposes the highest possible capacity within the predetermined range of 120000 ton ethanol per year. At the optimal, total net cost of ethanol production after deduced income from sale of by product is appeared 735.4 Euro per ton in the without biogas plant and 837 Euro per ton with biogas plant. This cost is 824.8 and 926.6 Euro per ton under subsidy on cotton at 80 Euro per ha for without and with biobas plant.

It is evident from the study that total cost of ethanol production with biogas facility in absolute term is less than without biogas facility but when by-product sale is deduced from cost, ethanol production cost with biogas facility became higher than without biogas. This is because the by-product from ethanol production which is used for biogas plant has high value of direct sale. Using of high value DDGS and pulp for biogas plant reduced by-product sale that increased net cost of ethanol production.

Table 8.2. Total raw material used, product and by-product production in the industry at optimal in different plant size.

Item	Under subsidy on cotton @ 55(є/h)							Sub_cot 80(є/h)
Plant size (kt)	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**120**
Quantity of wheat used (kt)	139.8	163.2	186.5	209.8	233.1	256.4	279.7	279.7
Quantity of sugar beet used (kt)	271.4	316.6	361.8	407.1	452.3	497.5	542.7	542.7
Dual price of wheat (є/t)	150.6	154.5	158.6	160.3	161.1	161.7	**164.4**	**199.3**
Dual price sugar beet (є/t)	27.9	28.4	28.7	28.9	29.1	29.8	**31.7**	**33.4**
Qty ethanol from wheat(kt)	41.8	48.8	55.7	62.7	69.7	76.7	83.6	83.6
Qty ethanol from beets (kt)	18.1	21.2	24.2	27. 3	30.3	33.3	36.3	36.3
Quantity of DDGS (kt)	44.7	52.2	59.7	67.1	74.6	82.1	89.5	89.5
Quantity of pulp (kt)	54.3	63.3	72.4	81.4	90.4	99.5	108.5	108.5

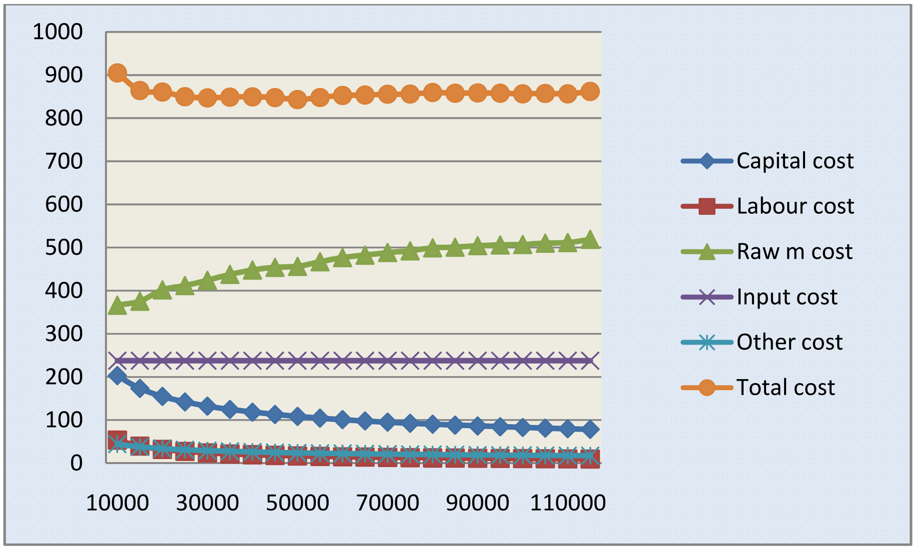


Figure 8.2 Cost and returns per ton of ethanol production (configuration 1)

8.4. Effect of policy change on ethanol production activity

Policy parameters created the boundary of the integrated agro-industrial model. Any change in policy parameter changes optimal allocation of resources thus cost effectiveness and productivity is also changes. The new policy adopted in Greek agriculture in 2009 that ubsidy on cotton cultivation at the rate of 80 Euro per ha that was 55 euro per ha in CAP 2003 is applied on the model. Effect of imposing this policy change parameter is illustrated in Figure 8.3 and 8.4. It is observed from the Figure 8.3 that after imposing subsidy on cotton at 80 Euro per ha instead of 55 Euro per ha, raw material cost for the industry is increased substantially. Increased subsidy on cotton made the energy crop more competitive that increased raw material cost as well as total cost of the industry. As an impact of increased raw material cost, cost composition as well as profitability of the ethanol production activity is affected. It is observed from the Figure 8.4 that total cost of ethanol production per ton ethanol under subsidy on cotton at the rate of 80 Euro per ha is minimum at 20kt ethanol plant size but the minimum cost under subsidy on cotton at the rate of 55 Euro per ha was at 50kt ethanol plant size.

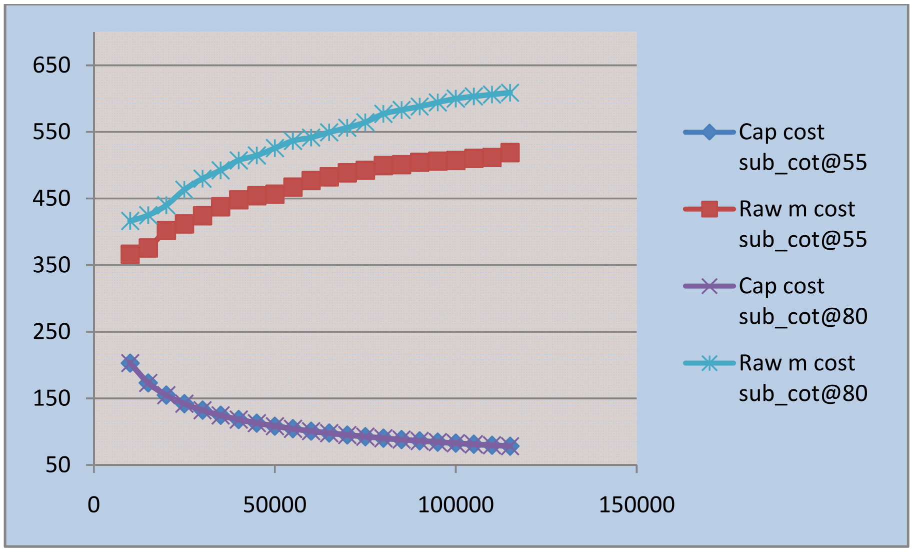


Figure 8.3. Effect of policy change on cost item

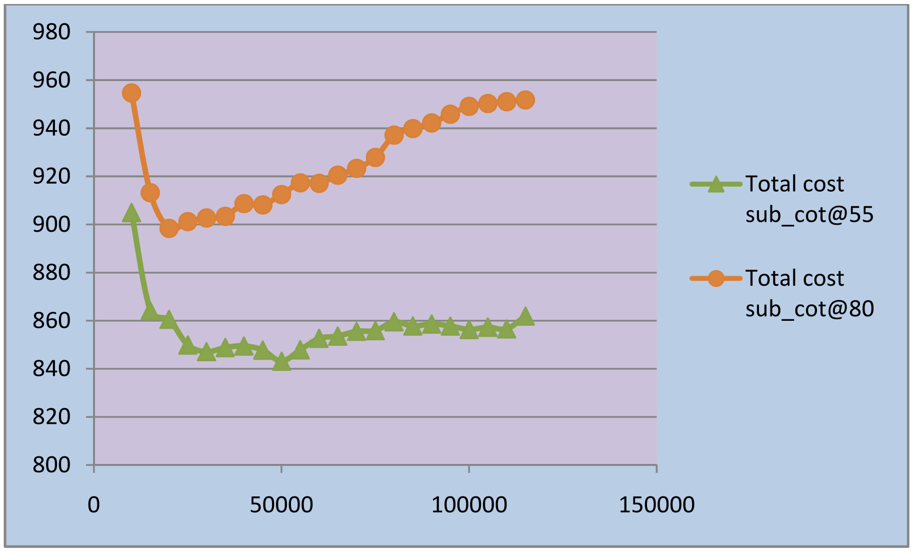


Figure 8.4. Effect of policy change on total cost and model optimization

8.5 GHG performance of bioethanol production system

Environmental impact of bioethanol production in the sugar industry has been estimated in terms of net change in CO_2eq emission at the atmosphere. There are four stages from where CO_2 emission is considered for bioethanol. First one is at the agricultural sector during feedstock production, secondly during transportation, thirdly during transformation stage in the industry and finally in the combustion stage. Bioethanol combustion is considered GHG neutral but it avoids the quantity emission by equivalent amount gasoline that would be replaced by bioethanol.

Different scenarios are considered to estimate GHG performance of bioethanol production system. Firstly the absolute CO_2eq emission considering only direct land use change (LUC) for feedstock production, emission for transportation and for industrial transformation. In the second scenario, GHG emission for indirect land use change (iLUC) is considered. Introduction of energy crop changes crop mix in agriculture that changes GHG emission attributes in agriculture. Taking in to consideration change in crop mix, GHG differentials for without and with the cultivation of energy crop is evaluated within the regional boundary of Thessaly. In the third scenario, along with iLUC in regional boundary of Thessaly, global GHG potential is considered.

Introduction of energy crop in the model changes the crop mix that creates imbalances in the market demand and supply. For example, in the new cropping mix after introduction of energy crops, cotton, maize, soft wheat, durum wheat cultivation area is decreased that replaced by irrigated wheat and sugar beet that will be used for bioethanol production. As a result demand for wheat, maize exceed the supply in Greek market. Greece is net cotton exporter but shortage of wheat and maize for food must be met by importing. Wheat and maize import from Eastern Europe would be the most suitable for Greece because there is availability of land for wheat and maize cultivation in Eastern Europe and transportation cost will be much smaller than overseas. Considering this fact, life cycle GHG emission for the additional imported food grain (wheat and maize) is considered in the third scenario.

GHG emission for wheat and maize production in Eastern Europe is different from Greece because fossil energy use and yield in agricultural production is different. Life cycle GHG emission for wheat and maize in Eastern Europe is calculated from BioGrace GHG calculation database (BioGrace, 2010), can be seen in the Annexure V.

Bioethanol production activity produces DDGS a high value animal feed as by-product that is a substitute of soya cake. Soya cake in Greece is imported that might reduce by replacing with DDGS. In the third scenario, CO_2 avoided due to reduction of soya cake import is also incorporated. In terms of nutrient (protein) content, ratio for soya cake replace by DDGS is considered 0.78:1 (ADEME, 2006).

It is noted that, crop mix with or without ethanol is influenced by policy parameters. For example, a new policy adopted in 2009 in Greek agriculture that coupled subsidy on cotton cultivation at the rate of 80 Euro per ha that was 55 Euro per ha in 2003 new CAP reform, changes optimal crop mix that changes GHG attribute also. This policy change has also taken into consideration.

Results on GHG emission in different scenarios are presented in Table 8.3. For the first scenario with direct LUC, total emission in agriculture and transportation is always positive. On the other hand, CO_2 emission saved due to replacement of gasoline by ethanol is presented in negative sign. The total net emission, i.e., considering CO_2 save due to gasoline replaced by bioethanol is appeared in negative sign that expresses net CO_2 saving in ethanol production system. Total net CO_2 saving at optimal solution in different plant size is appeared increasing with the plant size increase but CO_2 emission savings per ton is decreasing. Total net CO_2 saving at optimal plant size of 120kt ethanol plant is 70.6kt and CO_2 saving per ton of ethanol at the optimal is 0.588 ton. Under the new policy of subsidy on cotton cultivation at the rate of 80 Euro per ha, total CO_2 emission saving in this case is appeared 71.1kt and CO_2 saving per ton ethanol is 0.593 ton.

Under the second scenario considering indirect land use change within regional boundary of Thessaly, net CO_2 emission change in agriculture and transportation is estimated by the differences in CO_2 emission with and without ethanol production. One can observe from the Table 8.3 that the net CO_2 emission in agriculture is negative. This means for the production of ethanol, introduction of energy crops reduces CO_2 emission in the agriculture i.e., CO_2 emission is saved in agriculture. The total net CO_2 emission including emission saved due to replacement of gasoline by ethanol at the optimal plant size of 120kt is appeared 171.9kt that contributed 1.432 ton CO_2 saving per ton of ethanol production. Under the policy of subsidy on cotton cultivation at 80 Euro per ha, total CO_2 emission saving is 159.1kt and emission savings per ton ethanol is 1.326 ton.

Under the third scenario considering global indirect land use change, including import and import substitution, GHG potential is more or less similar to the second scenario. Total CO_2

saving at the optimal plant size of 120kt is 172.6kt that contributed 1.438 ton CO_2 saving per ton of ethanol. Under the policy of subsidy on cotton cultivation at 80 Euro per ha, total CO_2 emission saving is appeared 198.4kt and emission savings per ton ethanol is 1.653 ton.

8.5.1. Cost of CO_2 saving

Note on Surplus allocation to farmers and other agents (Rozakis and Sourie, 2002)

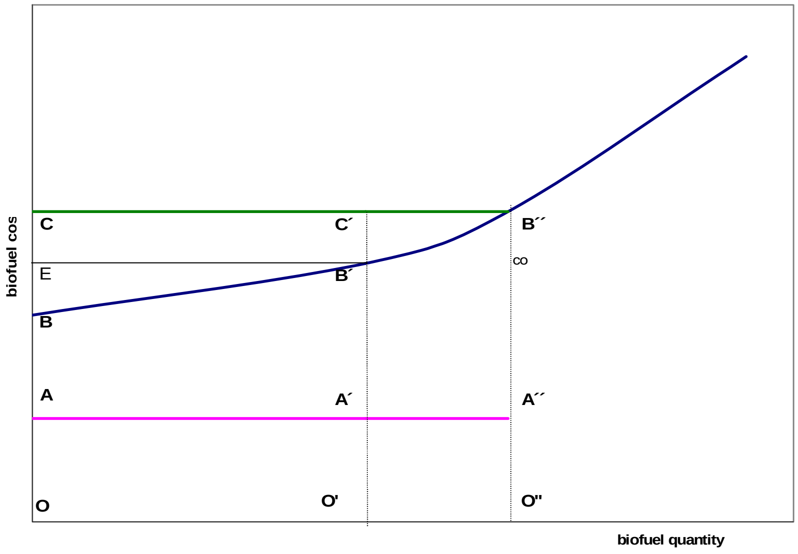
Dual prices that correspond to biomass availability constraints are equal the opportunity cost of the agricultural resource. If global surplus is denoted by *S* and marginal value of total subsidy is denoted by *eff* and maximal subsidy to biofuel is denoted by *maxsub*, the farmers' surplus, or farm income increase due to energy crop production is: *S* – *sff***maxsub*. The industry surplus is then equal to *eff***maxsub*. If the budgetary constraint is not bound, global surplus equal to farmers' surplus.

Tax exemption to biofuels
BB΄B΄΄: biofuel marginal cost curve =biomass opportunity cost + conversion cost - coproduct value
OA: biofuel market price (perfectly elastic demand)= equivalent gasoline value
OC: biofuel value=biofuel market price + tax exemption (AC)
OO΄΄: quantity produced in the equilibrium (biofuel value equal to its marginal cost)
CBB΄΄: producer (agricultural sector) surplus at the optimum
CB΄΄A΄΄A: total cost to the government of the biofuel support program at optimum

Tax exemption of biofuels under budgetary constraint
CC΄A΄A: total budget earmarked to biofuel
OO΄:biofuel quantity allowed to be produced (agreements approved by the government that depend on earmarked budget)
CA: tax exemption to biofuel (depends on budget, and industry lobbies)
EBB΄: producer (agricultural sector) surplus
ECC΄B΄: industry surplus

The integrated model can minimize social cost i.e., the deadweight loss (ABB´A´ :budget cost – agents´surpluses) determining tax exemption values per unit of biofuel volume given fixed amounts of government expenditure.

Figure 8.5. Economic surpluses generated by biofuel production



Cost of CO_2 saving is estimated on the basis of deadweight loss that the society has to pay for bioethanol production activity. Deadweight is the forgone benefit that the tax payers have to bear. Surplus generation and deadweight loss of bioethanol production activity is presented in Table 8.3. It is observed that at the optimal plant size of 120kt ethanol under the policy of subsidy on cotton cultivation at 55 Euro per ha, cost of ethanol production per litre is 0.58 Euro where as cost of equivalent amount of gasoline is 0.36 Euro thus 0.22 Euro per litre subsidy is required for ethanol to be competitive with gasoline. Total amount of subsidy for 120kt bioethanol is estimated 33.96 million Euro. On the other hand, the industry receive 0.64 Euro per litre of ethanol sale (800 Euro per ton) and bioethanol is tax free, hence the industry is getting 0.06 Euro surplus per litre of ethanol. Total amount of industrial surplus thus is 7.77 million Euro. The agricultural sector also generated 5.49 million Euro from feedstock sale over the production cost. The net loss of the society is derived by deducing total surplus gain by industry and agriculture from the total subsidy paid for ethanol activity. The dead weight loss for the optimum plant capacity is estimated 20.7 million Euro. For the same amount of ethanol production under the scenario of subsidy on cotton at 80 Euro per ha, agricultural surplus increased substantially, but surplus for the industry became negative because of high cost of raw material and deadweight loss become about double. In the context of environmental consideration, thus the deadweight loss of the ethanol production activity is considered as the cost of CO_2 saving. It is evident from the study that gasoline price is the prime factor that drives ethanol competitiveness and deadweight loss for the society also.

Table 8.3 Surplus generation and deadweight loss of bioethanol production system

Item	Under subsidy on cotton @ 55 (є/h)							Sub_cot 80 (є/h)
Plant size (kt)	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**120**
Ethanol cost (euro per litre)	0.57	0.57	0.58	0.58	0.57	0.57	0.58	0.65
Average gasoline cost for 1litre ethanol equivalent (ex factory fob)*	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Diff: Ethanol-Gasoline (euro)	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.30
Total subsidy requirement (1)(mє)	**16.09**	**18.98**	**22.01**	**24.68**	**27.19**	**29.93**	**33.96**	**44.68**
Industry surplus (2)(mє)**	**4.77**	**5.36**	**5.81**	**6.62**	**7.58**	**8.31**	**7.77**	**-2.96**
Wheat farm surplus (mє)	1.73	2.28	2.95	3.27	3.42	3.57	4.25	6.48
Sugar beet farm surplus (mє)	0.69	0.72	0.25	0.18	0.16	0.39	1.23	0.81
Total Agricultural Surplus (3)(mє)	**2.42**	**3.00**	**3.20**	**3.45**	**3.58**	**3.97**	**5.49**	**7.29**
Dead weight loss (1-2-3)(mє)	**8.90**	**10.62**	**13.01**	**14.61**	**16.03**	**17.65**	**20.70**	**40.36**

* Average ex factory gasoline (premium unleaded 10ppm fob) cost in 2010 is 0.448 Euro per litre; cost of gasoline for the amount of 1litre ethanol equivalent is 0.448×0.8=0.3585 Euro.

** Industry surplus is the difference between ethanol sale price and production cost. Ethanol sale price is exogenous and considered 800 Euro per ton; ethanol price per litre is 800/1262 =0.6339 Euro.

Cost of CO_2 saving per ton of ethanol production under the first scenario with direct land use change is appeared high and increasing with increase of plant size (Table 8.4). At the optimal plant size of 120kt ethanol plant, cost of CO_2 saving is appeared 293.3Euro per ton. On the other hand under the second scenario considering indirect land use change within the regional boundary of Thessaly, cost of CO_2 saving per ton of ethanol production is decreasing with plant size increase. Cost of CO_2 saving at the optimal plant size of 120kt ethanol plant is 120.5 Euro per ton. Under the third scenario considering global indirect land use change and import and import substitution, trend of CO_2 saving cost is unstable within a limited range from 104.2 to 110.8 Euro per ton CO_2eq for different plant size. At the optimal plant size of 120kt ethanol plant, cost of CO_2 saving is appeared 119.9 Euro per ton. Under the policy of subsidy on cotton cultivation at 80 Euro per ha, cost of CO_2 saving at the first, second and third scenario is appeared 567.2, 253.6 and 203.4 Euro per ton, respectively.

It is evident from the study that in absolute terms, on an average 24% CO_2eq emission for bioethanol production is caused by feedstock production and 75% emission is occurred in industrial processing whereas only 1% is dedicated for transportation. With the optimal plant size of 120kt ethanol per year, 302.6kt CO_2 emission caused by gasoline can be avoided by replacing with ethanol. Thus, significant amount of CO_2 emission can be avoided both in agricultural sector by the introduction of energy crop in crop mix and by the replacement of gasoline with bioethanol but cost of CO_2 saving is appeared to be expensive.

Table 8.4 GHG emission in the ethanol production system (in kt CO_2eq)

	Under subsidy on cotton @ 55(є/h)							Sub_cot 80 (є/h)
Plant size (kt)	60	70	80	90	100	110	120	120
Direct Land Use Change (LUC) considering only wheat and sugar beet production (kt)								
CO_2 emission in agriculture	25.6	30.5	35.6	40.5	45.3	50.3	55.6	55.1
CO_2 in transportation	0.69	0.823	0.967	1.1	1.24	1.38	1.52	1.51
Total CO_2 emission	**26.3**	**31.4**	**36.5**	**41.6**	**46.56**	**51.7**	**57.1**	**56.6**
Indirect LUC (regional boundaries within Thessaly) (kt)								
Net CO_2 emission in agriculture	-20.5	-24.1	-28.2	-33.9	-37.5	-40.9	-45.2	-32.7
Net CO_2 in transportation	0.47	0.56	0.65	0.76	0.86	0.96	1.05	1.2
Total net CO_2 regional_iLUC	**-20.1**	**-23.5**	**-27.5**	**-33.1**	**-36.6**	**-40.0**	**-44.2**	**-31.4**
Indirect LUC import (different crop mix and replaced food crops by imports) (kt)								
Net CO_2 emission in agriculture	22.8	27.9	32.8	37.6	40.3	42.3	47.5	18.2
Net CO_2 in transportation	7.3	8.9	10.5	12.1	12.9	13.5	15.1	5.9
CO_2 avoided_reduc_soya cake_imp	-31.7	-36.9	-42.2	-47.5	-52.8	-58.1	-63.4	-63.4
Total net CO_2 for import_iLUC	**-1.5**	**-0.1**	**1.1**	**2.1**	**0.3**	**-2.3**	**-0.7**	**-39.2**
CO_2 emission at the industrial transformation (kt)								
CO_2 for electricity	15.6	18.2	20.7	23.3	25.9	28.5	31.1	31.1
CO_2 for steam	71.9	83.9	95.8	107.8	119.8	131.8	143.8	143.8
Total CO_2 for industrial processing	**87.4**	**102.0**	**166.6**	**131.2**	**145.7**	**160.3**	**174.9**	**174.9**
CO_2 gasoline to be replace	**-151.3**	**-176.5**	**-201.7**	**-226.9**	**-252.2**	**-277.4**	**-302.6**	**-302.6**
Total net CO_2 emission in different scenarios (kt)								
Total net CO_2 direct LUC (save)	-37.5	-43.1	-48.6	-54.2	-59.8	-65.3	-70.6	-71.1
Total net CO_2 regional_iLUC	-83.9	-98.1	-112.7	-128.9	-143.1	-157.1	-171.9	-159.1
Total net CO_2 include import iLUC	-85.4	-98.1	-111.6	-126.8	-142.7	-159.4	-172.6	-198.4
Total net CO_2 emission per ton of ethanol (t)								
Net CO_2 direct LUC per t ethanol	-0.626	-0.616	-0.607	-0.602	-0.598	-0.594	-0.588	-0.593
Net CO_2 region_iLUC per t ethanol	-1.398	-1.401	-1.409	-1.432	-1.431	-1.428	-1.432	-1.326
Net CO_2 incl.import_iLUC per t eth	-1.424	-1.402	-1.395	-1.409	-1.427	-1.449	-1.438	-1.653
Cost of CO_2 saving								
Total cost of CO_2 saving (million є)	**8.9**	**10.6**	**13.0**	**14.6**	**16.0**	**17.7**	**20.7**	**40.4**
Cost of CO_2 saving direct LUC (є/t)	236.9	246.2	267.6	269.8	267.8	270.3	293.3	567.2
Cost of CO_2 saving_reg_ iLUC(є/t)	106.1	108.3	115.4	113.4	112.0	112.4	120.5	253.6
Cost of CO_2 save.inc.imp iLUC (є/t)	104.2	108.2	116.5	115.3	112.3	110.8	119.9	203.4

8.6 GHG performance of bioethanol production with biogas plant

Instead of direct selling of DDGS and pulp as by-product from ethanol production, a second configuration of ethanol plant with biogas unit is considered to evaluate alternative economic and environmental performance. CO_2 emission during the industrial processing is the biggest part of total emission in ethanol production system. Electricity required for ethanol plant can be met by electricity generated by a biogas plant using DDGS and pulp. Moreover, CO_2 credit from electricity sale is added to this configuration.

GHG performance of an ethanol plant with biogas plant is presented in Table 8.5. Under the first scenario considering only direct land use change, GHG performance is substantially improved compare to without biogas. Total net CO_2 emission savings at optimal plant size of 120kt ethanol plant is 107.7kt and CO_2 saving per ton of ethanol production is 0.898 ton. GHG performance under the second scenario considering indirect land use change within regional boundary of Thessaly is also better than without biogas. Total net CO_2 savings at optimal plant size of 120kt ethanol plant is 209kt and CO_2 saving per ton of ethanol production is 1.742 ton. On the other hand, GHG performance under the third scenario considering global indirect land use change and import and import substitution, it is worse than without biogas. Total net CO_2 savings at optimal plant size of 120kt ethanol plant is 146.4kt and CO_2 saving per ton of ethanol production is 1.22 ton. DDGS produce in the ethanol plant is utilized for biogas plant hence it cannot be substitute for the reduction of soya cake import.

Though CO_2 emission saving with biogas facility under first and second scenarios is higher than without biogas but cost of CO_2 saving is appeared higher with biogas facility under all scenarios. High value DDGS and pulp from ethanol plant that used in biogas plant reduced by-product sale that reduce industry surplus substantially hence total deadweight loss is increased as a result cost of CO_2 saving increased significantly. Cost per ton of CO_2 saving at the optimal plant size of 120kt ethanol plant in the first, second and third scenario is 418.8 215.9 and 308.3 Euro and under the policy of subsidy on cotton cultivation at 80 Euro per ha, cost of CO_2 saving at the above mentioned three scenarios is appeared 815.7, 357.6 and 570.5 Euro per ton, respectively. It is evident from the study that subsidy on one crop affected other crop profitability and GHG emission attributes also.

Table 8.5 GHG emission in the ethanol production system with biogas plant (in kt CO_2eq)

	Under subsidy on cotton @ 55(є/h)							Sub_cot 80 (є/h)
Plant size (kt)	60	70	80	90	100	110	120	70.938
Direct Land Use Change (LUC) considering only wheat and sugar beet production (kt)								
CO_2 emission in agriculture	25.6	30.5	35.6	40.5	45.3	50.3	55.6	31.1
CO_2 in transportation	0.69	0.823	0.967	1.1	1.24	1.38	1.52	0.841
Total CO_2 emission	**26.3**	**31.4**	**36.5**	**41.6**	**46.56**	**51.7**	**57.1**	**31.9**
Indirect LUC (regional boundaries within Thessaly) (kt)								
Net CO_2 emission in agriculture	-20.5	-24.1	-28.2	-33.9	-37.5	-40.9	-45.2	-24.5
Net CO_2 in transportation	0.47	0.56	0.65	0.76	0.86	0.96	1.05	0.569
Total net CO_2 regional_iLUC	**-20.1**	**-23.5**	**-27.5**	**-33.1**	**-36.6**	**-40.0**	**-44.2**	**-23.9**
Indirect LUC import (different crop mix and replaced food crops by imports) (kt)								
Net CO_2 emission in agriculture	22.8	27.9	32.8	37.6	40.3	42.3	47.5	28.1
Net CO_2 in transportation	7.3	8.9	10.5	12.1	12.9	13.5	15.1	8.9
Total net CO_2 for import_iLUC	**30.1**	**36.9**	**43.3**	**49.6**	**53.1**	**55.8**	**62.6**	**37.1**
CO_2 emission at the industrial transformation (kt)								
CO_2 save by excess electricity sale	-3.0	-3.5	-4.0	-4.5	-5.0	-5.5	-6.0	-3.5
CO_2 for steam	71.9	83.9	95.8	107.8	119.8	131.8	143.8	85.0
Total CO_2 for industrial processing	**68.9**	**80.3**	**91.8**	**103.3**	**114.8**	**126.3**	**137.7**	**81.4**
CO_2 gasoline to be replace	**-151.3**	**-176.5**	**-201.7**	**-226.9**	**-252.2**	**-277.4**	**-302.6**	**-178.9**
Total net CO_2 emission in different scenarios (kt)								
Total net CO_2 direct LUC (save)	-56.1	-64.8	-73.3	-82.0	-90.8	-99.4	-107.7	-43.6
Total net CO_2 regional_iLUC	-102.5	-119.7	-137.4	-156.7	-174.0	-191.1	-209.0	-99.4
Total net CO_2 include import_iLUC	-72.3	-82.8	-94.1	-107.1	-120.9	-135.3	-146.4	-62.3
Total net CO_2 emission per ton of ethanol (t)								
Net CO_2 direct LUC per t ethanol	-0.936	-0.926	-0.917	-0.911	-0.908	-0.903	-0.898	-0.614
Net CO_2 region_iLUC per t ethanol	-1.708	-1.710	-1.718	-1.742	-1.740	-1.737	-1.742	-1.401
Net CO_2 incl.import_iLUC per t eth	-1.205	-1.183	-1.176	-1.190	-1.209	-1.230	-1.220	-0.878
Cost of CO_2 saving								
Total cost of CO_2 saving (million є)	**21.4**	**25.1**	**29.5**	**33.1**	**36.5**	**40.1**	**45.1**	**35.6**
Cost per ton saving direct LUC (є/t)	380.8	387.3	401.9	403.3	401.8	403.5	418.8	815.7
Cost per ton saving_reg_ iLUC(є/t)	208.6	209.6	214.5	211.0	209.6	209.8	215.9	357.6
Cost per ton save.inc.imp iLUC (є/t)	295.5	303.1	313.3	308.9	301.8	296.3	308.3	570.5

CHAPTER IX: CONCLUSIONS

This study attempts an economic and environmental evaluation of bio-ethanol production in the context of the ex-sugar industry in Thessaly taking into consideration recent changes in the Common Market Organization for sugar in the EU and options considered by the Hellenic Sugar Industries.

Model results for validation test shows that optimal cropping plan in the base year context closely approximates observed surfaces cultivated at the regional level by main crops in the year 2002. This proves that the selected model specification can be used to perform predictions of the farmers' behavior under different parameters' sets.

In the optimal solution when the model runs under the CAP 2003 regime (scenario 2), cotton cultivation is significantly decreased, replaced by maize, alfalfa and soft wheat. Also sugar beet almost disappears due to drastic price reductions.

Introduction of energy crops in the model under new CAP causes significant changes in crop mix and evolution of crop mix with the increase of plant size is appeared prominently. To satisfy demand for the industry, wheat and sugar beet takes more area from other crops as a result with the increase of plant size, irrigated wheat and sugar beet area is increasing but the other crops like soft wheat, durum wheat, maize cotton are decreasing. Tobacco, dry cotton and maize for fodder are disappeared and potato and tomato area remained unchanged, irrespective of plant size. Alfalfa is slightly increasing due to cross compliance constraints included in the model.

Under the revised policy of subsidy on cotton cultivation at the rate of 80 Euro per ha, cotton cultivation became competitive as a result cotton area is increased substantially and soft cotton appeared to be cultivated and wheat, maize, alfalfa area is decreased.

Optimal size of the integrated agro-industry model is determined under various policy and technical assumptions. Spreading fixed charges over greater production volume, total cost is decreasing with plant size increase. On the other hand raw material cost, the major part of total cost varying from 50-60 % of total cost is increasing with plant size. Minimum total cost per ton of ethanol production is found at the plant size of 50kt. The model maximizes total profit, thus it proposes the highest possible capacity within the predetermined range of 120000 ton ethanol per year.

In terms of economic performance, the ethanol activity has potentiality of surpluses both in the industrial and agricultural sector. Moreover, bioethanol activity would reduce gasoline import that will save foreign currency and will reduce dependency on imported fossil fuel.

Environmental performance of bioethanol production system is evaluated under different scenarios. GHG performance considering indirect land use change due to introduction of energy crop in the model appeared better than considering only direct land use change. In reality, displacement and replacement among arable crops also reveal significant differences in GHG costs or gain. It is evident that significant amount of CO_2 emission can be avoided both in agricultural sector by the introduction of energy crop in crop mix and by the replacement of gasoline with bioethanol but cost of CO_2 saving is appeared to be expensive.

The alternative scheme with biogas facility is appeared less interesting than without biogas plant. Direct sale of DDGS and pulp rather than use for biogas is appeared more profitable. In terms of environmental performance, ethanol plant with biogas facility is in favourable condition but cost of CO_2 saving is higher than without biogas plant.

Under the policy of coupled area subsidy on cotton cultivation at 80 Euro per ha, energy crops became more vulnerable as a result opportunity cost of land dedicated to cultivate energy crops is increasing, thus feedstock cost for the industry is increased that leads to increase total cost of ethanol production. Increased cotton subsidy drives energy crops to marginal land that increase GHG emission both for direct and indirect land use change, hence cost of CO_2 saving is also increases under this new policy.

It is evident from the study that the integrated agro-industry model successfully accommodated different policy scenarios to evaluate bioethanol production potentiality at the Larissa sugar factory in Thessaly. The model takes into account the policy parameter in changing condition and generated results of different policy scenarios simultaneously.

It is observed in the study that, restricting of the Larissa sugar factory to an ethanol production plant potentially economically advantageous to the Greek producers as because the farmer can gain satisfactory returns from their farm production and can avoid the support cut on sugar beet production at the same time the Greek sugar producer can survive through restructuring the industry and can accommodate with the EU's CMO for sugar compulsory quota cuts.

Further research should be conducted to take into account uncertainty. Uncertainty issues concerning not only demand side (ethanol and by-products price volatility) but also supply side (changing policy contexts and competitive crop price volatility) need to be addressed in order to determine ethanol profitability confidence levels. Also additional technical configurations including recent research findings on promising crops such as sorghum could increase farmers' gains.

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APPENDIX I: Cost and Returns of sugarcane production in Bangladesh

Cost and return of sugarcane production of sample farmers in Bangladesh (Euro)

Items	F-1	F-2	F-3	F-4	F-5	Minimum	Maximum
Cost Items (per ha)							
Land preparation	39.92	39.92	39.92	39.92	39.92	39.92	39.92
Plantation/ Transplantation	59.88	56.14	56.14	58.22	59.88	56.14	59.88
Intercultural Operation	113.10	106.04	113.10	104.79	106.45	104.79	113.10
Harvesting	159.68	155.93	166.33	145.54	166.33	145.54	166.33
Seed Cost	99.80	109.78	109.78	116.43	99.80	99.80	116.43
Fertilizer	87.24	87.24	87.24	87.24	87.24	87.24	87.24
Pesticide	42.41	29.94	33.27	37.42	37.42	29.94	42.41
Transportation	89.82	94.81	99.80	94.81	99.80	89.82	99.80
Total Cost	**691.85**	**679.79**	**705.57**	**684.36**	**696.84**	**679.79**	**705.57**
Yield (ton/ha)	75.42	81.01	83.80	78.21	83.80	75.42	83.80
Price (Euro/ton)	16.67	16.67	16.67	16.67	16.67		
Total Return	**1257.45**	**1350.60**	**1397.17**	**1304.03**	**1397.17**	**1257.45**	**1397.17**
Net Return	**565.61**	**670.81**	**691.60**	**619.66**	**700.33**	**565.61**	**700.33**

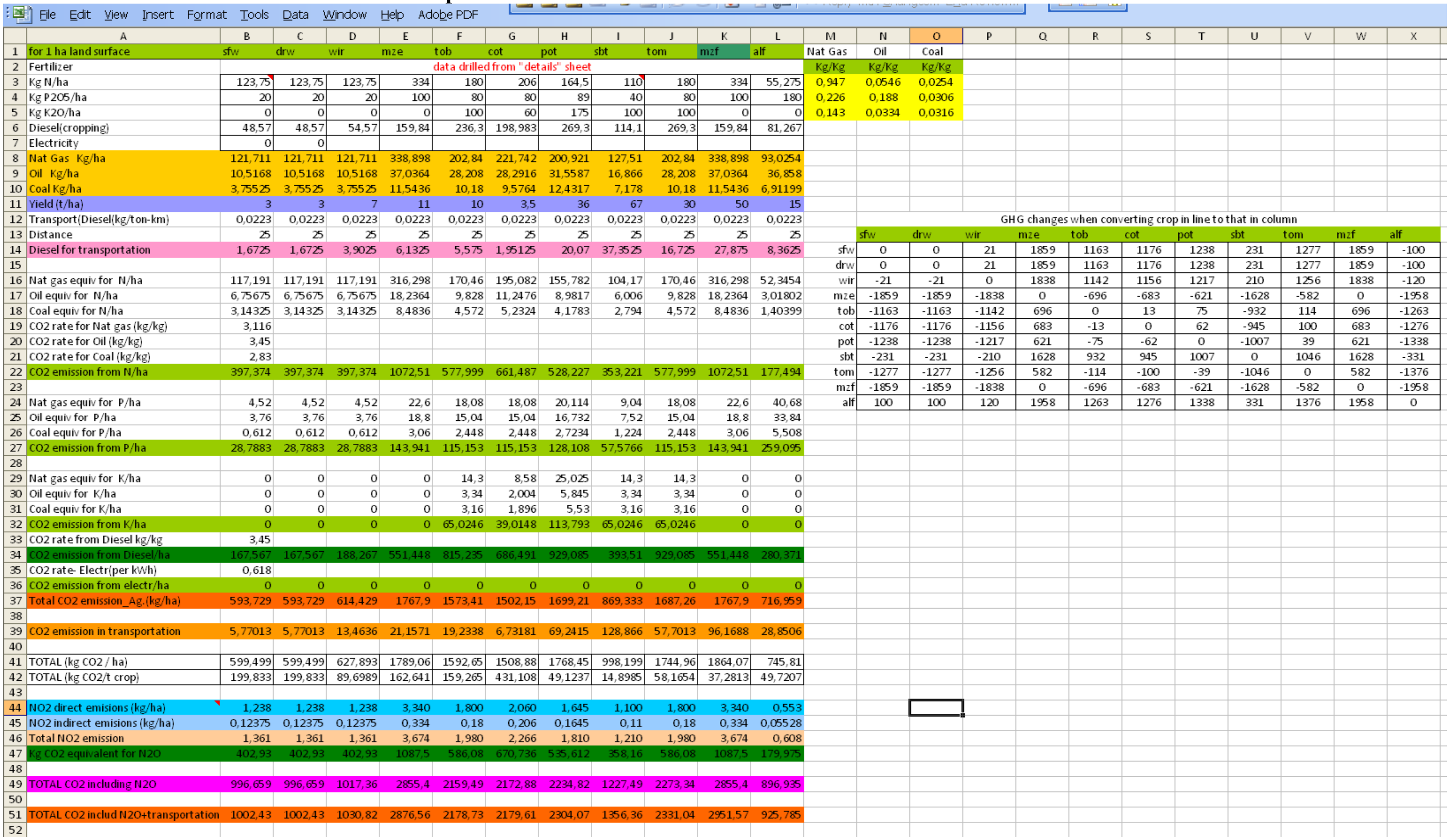
Source: Field survey

APPENDIX II: Map of Bangladesh indicating sugar factory and ethanol plant

APPENDIX III: Fossil input requirement for crop cultivation

Item	Crops										
	sft	drw	wir	mze	tob	cot	pot	sbt	tom	mzf	alf
Diesel (lit./ha)	48.57	48.57	54.57	159.8	236.3	199	269.3	114.1	269.3	159.84	81.27
Fertilizer											
N (kg/ha)	123.8	123.8	123.8	334	180	206	164.5	110	180	334	55.28
P_2O_5 (kg/ha)	20	20	20	100	80	80	89	40	80	100	180
K_2O (kg/ha)	0	0	0	0	100	60	175	100	100	0	0

APPENDIX IV: GHG emission calculation per ha in excel



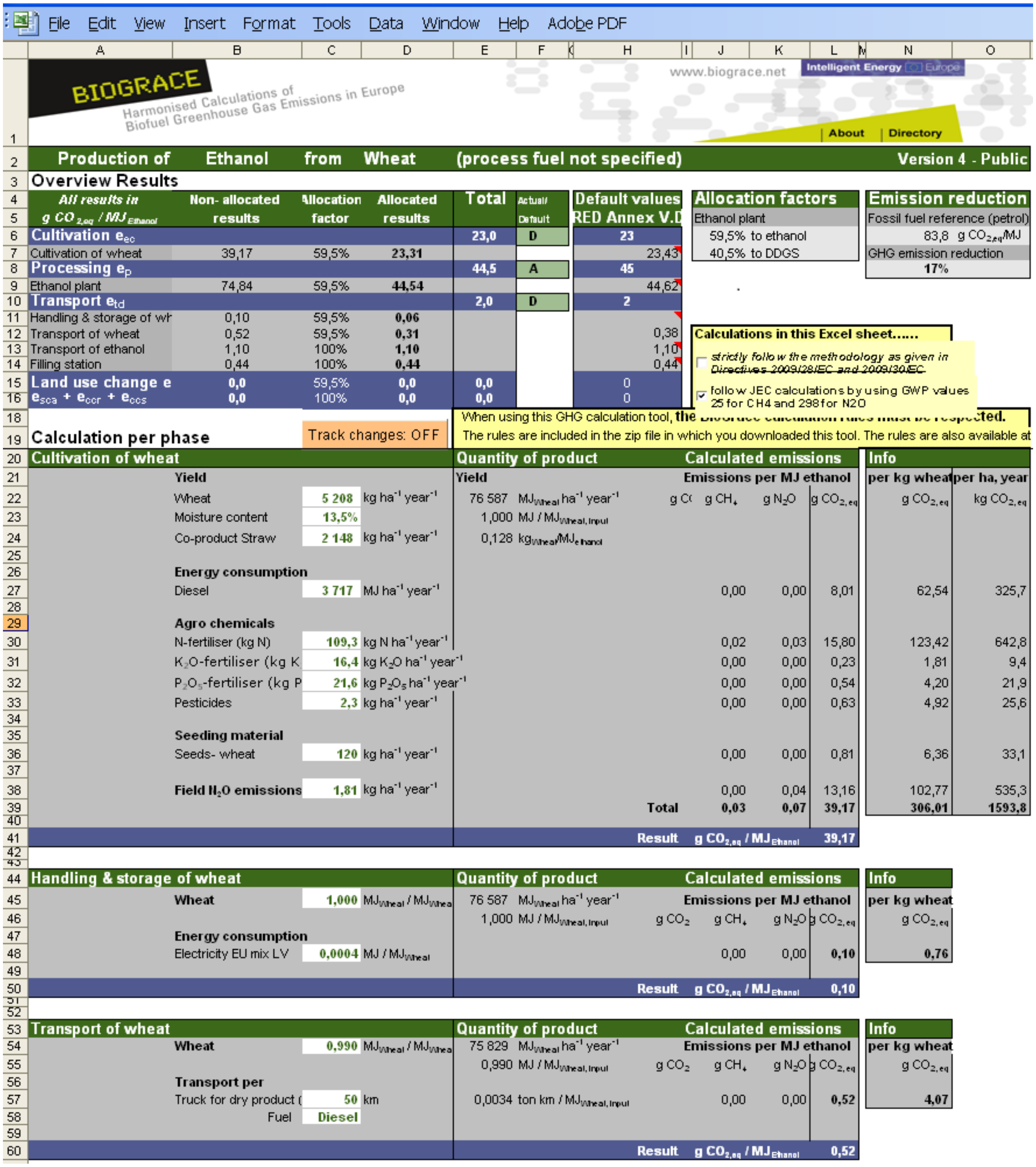
	A	B	C	D	E	F	G	H	I	J	K	L
1	for 1 ha land surface	sfw	drw	wir	mze	tob	cot	pot	sbt	tom	mzf	alf
2	Fertilizer	data drilled from "details" sheet										
3	Kg N/ha	123,75	123,75	123,75	334	180	206	164,5	110	180	334	55,275
4	Kg P2O5/ha	20	20	20	100	80	80	89	40	80	100	180
5	Kg K2O/ha	0	0	0	0	100	60	175	100	100	0	0
6	Diesel(cropping)	48,57	48,57	54,57	159,84	236,3	198,983	269,3	114,1	269,3	159,84	81,267
7	Electricity	0	0									
8	Nat Gas Kg/ha	121,711	121,711	121,711	338,898	202,84	221,742	200,921	127,51	202,84	338,898	93,0254
9	Oil Kg/ha	10,5168	10,5168	10,5168	37,0364	28,208	28,2916	31,5587	16,866	28,208	37,0364	36,858
10	Coal Kg/ha	3,75525	3,75525	3,75525	11,5436	10,18	9,5764	12,4317	7,178	10,18	11,5436	6,91199
11	Yield (t/ha)	3	3	7	11	10	3,5	36	67	30	50	15
12	Transport(Diesel(kg/ton-km)	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223	0,0223
13	Distance	25	25	25	25	25	25	25	25	25	25	25
14	Diesel for transportation	1,6725	1,6725	3,9025	6,1325	5,575	1,95125	20,07	37,3525	16,725	27,875	8,3625
15												
16	Nat gas equiv for N/ha	117,191	117,191	117,191	316,298	170,46	195,082	155,782	104,17	170,46	316,298	52,3454
17	Oil equiv for N/ha	6,75675	6,75675	6,75675	18,2364	9,828	11,2476	8,9817	6,006	9,828	18,2364	3,01802
18	Coal equiv for N/ha	3,14325	3,14325	3,14325	8,4836	4,572	5,2324	4,1783	2,794	4,572	8,4836	1,40399
19	CO2 rate for Nat gas (kg/kg)	3,116										
20	CO2 rate for Oil (kg/kg)	3,45										
21	CO2 rate for Coal (kg/kg)	2,83										
22	CO2 emission from N/ha	397,374	397,374	397,374	1072,51	577,999	661,487	528,227	353,221	577,999	1072,51	177,494
23												
24	Nat gas equiv for P/ha	4,52	4,52	4,52	22,6	18,08	18,08	20,114	9,04	18,08	22,6	40,68
25	Oil equiv for P/ha	3,76	3,76	3,76	18,8	15,04	15,04	16,732	7,52	15,04	18,8	33,84
26	Coal equiv for P/ha	0,612	0,612	0,612	3,06	2,448	2,448	2,7234	1,224	2,448	3,06	5,508
27	CO2 emission from P/ha	28,7883	28,7883	28,7883	143,941	115,153	115,153	128,108	57,5766	115,153	143,941	259,095
28												
29	Nat gas equiv for K/ha	0	0	0	0	14,3	8,58	25,025	14,3	14,3	0	0
30	Oil equiv for K/ha	0	0	0	0	3,34	2,004	5,845	3,34	3,34	0	0
31	Coal equiv for K/ha	0	0	0	0	3,16	1,896	5,53	3,16	3,16	0	0
32	CO2 emission from K/ha	0	0	0	0	65,0246	39,0148	113,793	65,0246	65,0246	0	0
33	CO2 rate from Diesel kg/kg	3,45										
34	CO2 emission from Diesel/ha	167,567	167,567	188,267	551,448	815,235	686,491	929,085	393,51	929,085	551,448	280,371
35	CO2 rate- Electr(per kWh)	0,618										
36	CO2 emission from electr/ha	0	0	0	0	0	0	0	0	0	0	0
37	Total CO2 emission_Ag.(kg/ha)	593,729	593,729	614,429	1767,9	1573,41	1502,15	1699,21	869,333	1687,26	1767,9	716,959
38												
39	CO2 emission in transportation	5,77013	5,77013	13,4636	21,1571	19,2338	6,73181	69,2415	128,866	57,7013	96,1688	28,8506
40												
41	TOTAL (kg CO2 / ha)	599,499	599,499	627,893	1789,06	1592,65	1508,88	1768,45	998,199	1744,96	1864,07	745,81
42	TOTAL (kg CO2/t crop)	199,833	199,833	89,6989	162,641	159,265	431,108	49,1237	14,8985	58,1654	37,2813	49,7207
43												
44	NO2 direct emisions (kg/ha)	1,238	1,238	1,238	3,340	1,800	2,060	1,645	1,100	1,800	3,340	0,553
45	NO2 indirect emisions (kg/ha)	0,12375	0,12375	0,12375	0,334	0,18	0,206	0,1645	0,11	0,18	0,334	0,05528
46	Total NO2 emission	1,361	1,361	1,361	3,674	1,980	2,266	1,810	1,210	1,980	3,674	0,608
47	Kg CO2 equivalent for N2O	402,93	402,93	402,93	1087,5	586,08	670,736	535,612	358,16	586,08	1087,5	179,975
48												
49	TOTAL CO2 including N2O	996,659	996,659	1017,36	2855,4	2159,49	2172,88	2234,82	1227,49	2273,34	2855,4	896,935
50												
51	TOTAL CO2 includ N2O+transportation	1002,43	1002,43	1030,82	2876,56	2178,73	2179,61	2304,07	1356,36	2331,04	2951,57	925,785
52												

	M	N	O
1	Nat Gas	Oil	Coal
2	Kg/Kg	Kg/Kg	Kg/Kg
3	0,947	0,0546	0,0254
4	0,226	0,188	0,0306
5	0,143	0,0334	0,0316

GHG changes when converting crop in line to that in column

	sfw	drw	wir	mze	tob	cot	pot	sbt	tom	mzf	alf
sfw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
drw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
wir	-21	-21	0	1838	1142	1156	1217	210	1256	1838	-120
mze	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
tob	-1163	-1163	-1142	696	0	13	75	-932	114	696	-1263
cot	-1176	-1176	-1156	683	-13	0	62	-945	100	683	-1276
pot	-1238	-1238	-1217	621	-75	-62	0	-1007	39	621	-1338
sbt	-231	-231	-210	1628	932	945	1007	0	1046	1628	-331
tom	-1277	-1277	-1256	582	-114	-100	-39	-1046	0	582	-1376
mzf	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
alf	100	100	120	1958	1263	1276	1338	331	1376	1958	0

APPENDIX V: BioGrace Model for GHG calculation



Production of Ethanol from Wheat (process fuel not specified) Version 4 - Public

Overview Results

All results in g $CO_{2,eq}$ / $MJ_{Ethanol}$	Non- allocated results	Allocation factor	Allocated results	Total	Actual/ Default	Default values RED Annex V.D
Cultivation e_{ec}				23,0	D	23
Cultivation of wheat	39,17	59,5%	23,31			23,43
Processing e_p				44,5	A	45
Ethanol plant	74,84	59,5%	44,54			44,62
Transport e_{td}				2,0	D	2
Handling & storage of wh	0,10	59,5%	0,06			
Transport of wheat	0,52	59,5%	0,31			0,38
Transport of ethanol	1,10	100%	1,10			1,10
Filling station	0,44	100%	0,44			0,44
Land use change e	0,0	59,5%	0,0	0,0		0
$e_{sca} + e_{ccr} + e_{ccs}$	0,0	100%	0,0	0,0		0

Allocation factors
Ethanol plant
59,5% to ethanol
40,5% to DDGS

Emission reduction
Fossil fuel reference (petrol)
83,8 g $CO_{2,eq}$/MJ
GHG emission reduction
17%

Calculations in this Excel sheet......

☐ ~~*strictly follow the methodology as given in Directives 2009/28/EC and 2009/30/EC*~~

☑ follow JEC calculations by using GWP values 25 for CH4 and 298 for N2O

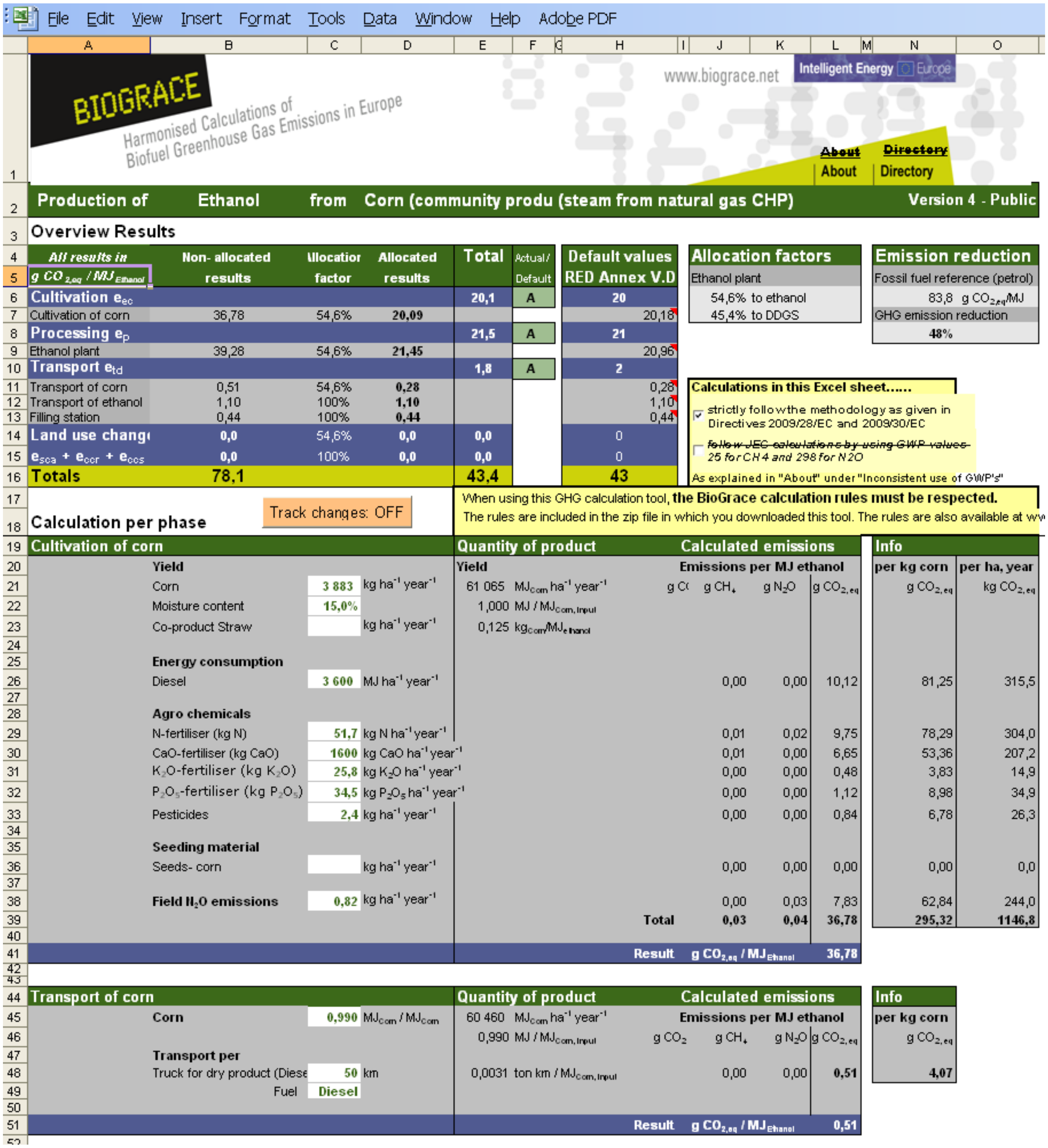
When using this GHG calculation tool, **the** … **cted.**
The rules are included in the zip file in which you downloaded this tool. The rules are also available at

Calculation per phase

Cultivation of wheat			Quantity of product	Calculated emissions				Info	
Yield			Yield	Emissions per MJ ethanol				per kg wheat	per ha, year
Wheat	5 208	kg ha^{-1} $year^{-1}$	76 587 MJ_{Wheat} ha^{-1} $year^{-1}$	g C(	g CH_4	g N_2O	g $CO_{2,eq}$	g $CO_{2,eq}$	kg $CO_{2,eq}$
Moisture content	13,5%		1,000 MJ / $MJ_{Wheat, input}$						
Co-product Straw	2 148	kg ha^{-1} $year^{-1}$	0,128 $kg_{Wheat}/MJ_{ethanol}$						
Energy consumption									
Diesel	3 717	MJ ha^{-1} $year^{-1}$			0,00	0,00	8,01	62,54	325,7
Agro chemicals									
N-fertiliser (kg N)	109,3	kg N ha^{-1} $year^{-1}$			0,02	0,03	15,80	123,42	642,8
K_2O-fertiliser (kg K	16,4	kg K_2O ha^{-1} $year^{-1}$			0,00	0,00	0,23	1,81	9,4
P_2O_5-fertiliser (kg P	21,6	kg P_2O_5 ha^{-1} $year^{-1}$			0,00	0,00	0,54	4,20	21,9
Pesticides	2,3	kg ha^{-1} $year^{-1}$			0,00	0,00	0,63	4,92	25,6
Seeding material									
Seeds- wheat	120	kg ha^{-1} $year^{-1}$			0,00	0,00	0,81	6,36	33,1
Field N_2O emissions	1,81	kg ha^{-1} $year^{-1}$			0,00	0,04	13,16	102,77	535,3
				Total	**0,03**	**0,07**	**39,17**	**306,01**	**1593,8**
				Result	**g $CO_{2,eq}$ / $MJ_{Ethanol}$**		**39,17**		

Handling & storage of wheat			Quantity of product	Calculated emissions				Info
Wheat	1,000	MJ_{Wheat} / MJ_{Whea}	76 587 MJ_{Wheat} ha^{-1} $year^{-1}$	Emissions per MJ ethanol				per kg wheat
			1,000 MJ / $MJ_{Wheat, input}$	g CO_2	g CH_4	g N_2O	g $CO_{2,eq}$	g $CO_{2,eq}$
Energy consumption								
Electricity EU mix LV	0,0004	MJ / MJ_{Wheat}			0,00	0,00	0,10	0,76
				Result	**g $CO_{2,eq}$ / $MJ_{Ethanol}$**		**0,10**	

Transport of wheat			Quantity of product	Calculated emissions				Info
Wheat	0,990	MJ_{Wheat} / MJ_{Whea}	75 829 MJ_{Wheat} ha^{-1} $year^{-1}$	Emissions per MJ ethanol				per kg wheat
			0,990 MJ / $MJ_{Wheat, input}$	g CO_2	g CH_4	g N_2O	g $CO_{2,eq}$	g $CO_{2,eq}$
Transport per								
Truck for dry product (	50	km	0,0034 ton km / $MJ_{Wheat, input}$		0,00	0,00	0,52	4,07
Fuel	Diesel							
				Result	**g $CO_{2,eq}$ / $MJ_{Ethanol}$**		**0,52**	



Production of Ethanol from Corn (community produ (steam from natural gas CHP) Version 4 - Public

Overview Results

All results in *g $CO_{2,eq}$ / $MJ_{Ethanol}$*	Non- allocated results	llocatior factor	Allocated results	Total	Actual / Default	Default values RED Annex V.D
Cultivation e_{ec}				**20,1**	**A**	**20**
Cultivation of corn	36,78	54,6%	**20,09**			20,18
Processing e_p				**21,5**	**A**	**21**
Ethanol plant	39,28	54,6%	**21,45**			20,96
Transport e_{td}				**1,8**	**A**	**2**
Transport of corn	0,51	54,6%	**0,28**			0,28
Transport of ethanol	1,10	100%	**1,10**			1,10
Filling station	0,44	100%	**0,44**			0,44
Land use chang	**0,0**	54,6%	**0,0**	**0,0**		0
e_{sca} + e_{ccr} + e_{ccs}	**0,0**	100%	**0,0**	**0,0**		0
Totals	**78,1**			**43,4**		**43**

Allocation factors

Ethanol plant
54,6% to ethanol
45,4% to DDGS

Emission reduction

Fossil fuel reference (petrol)
83,8 g $CO_{2,eq}$/MJ
GHG emission reduction
48%

Calculations in this Excel sheet......

☑ strictly follow the methodology as given in Directives 2009/28/EC and 2009/30/EC

☐ *~~follow JEC calculations by using GWP values~~ 25 for CH4 and 298 for N2O*

As explained in "About" under "Inconsistent use of GWP's"

Track changes: OFF

When using this GHG calculation tool, **the BioGrace calculation rules must be respected.**
The rules are included in the zip file in which you downloaded this tool. The rules are also available at ww

Calculation per phase

Cultivation of corn			**Quantity of product**	**Calculated emissions**				**Info**	
Yield			**Yield**	**Emissions per MJ ethanol**				**per kg corn**	**per ha, year**
Corn	3 883	kg ha^{-1} year^{-1}	61 065 MJ_{Corn} ha^{-1} year^{-1}	g C(	g CH_4	g N_2O	g $CO_{2,eq}$	g $CO_{2,eq}$	kg $CO_{2,eq}$
Moisture content	15,0%		1,000 MJ / $MJ_{Corn,input}$						
Co-product Straw		kg ha^{-1} year^{-1}	0,125 kg_{Corn}/$MJ_{ethanol}$						
Energy consumption									
Diesel	3 600	MJ ha^{-1} year^{-1}			0,00	0,00	10,12	81,25	315,5
Agro chemicals									
N-fertiliser (kg N)	51,7	kg N ha^{-1} year^{-1}			0,01	0,02	9,75	78,29	304,0
CaO-fertiliser (kg CaO)	1600	kg CaO ha^{-1} year^{-1}			0,01	0,00	6,65	53,36	207,2
K_2O-fertiliser (kg K_2O)	25,8	kg K_2O ha^{-1} year^{-1}			0,00	0,00	0,48	3,83	14,9
P_2O_5-fertiliser (kg P_2O_5)	34,5	kg P_2O_5 ha^{-1} year^{-1}			0,00	0,00	1,12	8,98	34,9
Pesticides	2,4	kg ha^{-1} year^{-1}			0,00	0,00	0,84	6,78	26,3
Seeding material									
Seeds- corn		kg ha^{-1} year^{-1}			0,00	0,00	0,00	0,00	0,0
Field N_2O emissions	0,82	kg ha^{-1} year^{-1}			0,00	0,03	7,83	62,84	244,0
				Total	**0,03**	**0,04**	**36,78**	**295,32**	**1146,8**
				Result	**g $CO_{2,eq}$ / $MJ_{Ethanol}$**		**36,78**		

Transport of corn			**Quantity of product**	**Calculated emissions**				**Info**
Corn	0,990	MJ_{Corn} / MJ_{Corn}	60 460 MJ_{Corn} ha^{-1} year^{-1}	**Emissions per MJ ethanol**				**per kg corn**
			0,990 MJ / $MJ_{Corn,input}$	g CO_2	g CH_4	g N_2O	g $CO_{2,eq}$	g $CO_{2,eq}$
Transport per								
Truck for dry product (Diese	50	km	0,0031 ton km / $MJ_{Corn,input}$		0,00	0,00	**0,51**	**4,07**
Fuel	Diesel							
				Result	**g $CO_{2,eq}$ / $MJ_{Ethanol}$**		**0,51**	

APPENDIX VI: Mathematical specification of the model

Mathematical specification of the Model

Indices:	j	Crops: {sfw: Soft Wheat, drw: Hard Wheat, wir: Irrigated Wheat, mze: Maize, mzf: Maize for fodder, tob: Tobacco, cot: Cotton, cotd: Dry Cotton, sbt: Sugar Beet, tom: Tomato, pot: Potato, alf: Alfalfa, vik: Intercropped vetch}
	k	Crop(s) having demand curve with negative slope
	r	Irrigated crops: {tob, cot, mzf, wir, pot, sbt, tom, mze, alf, cot}
	rot	Rotational crops: {mze, mzf, tob, sbt, cot, tom}
	eth, ddgs, plp	Ethanol, DDGS: Dried Distillers Grains with Soluble, Pulp
	agri, ind	Agriculture, industry

Model parameters:

p_j	Price of crop *j*
y_j	Yield of crop j
s_j	Subsidy on output of crop *j*
sub_j	Subsidy on area cultivated by the crop *j*
v_j	Variable cost of crop *j*
$P_{\{eth,\ ddgs,\ plp)}$	Price of ethanol, Distilled Dry Grain Solubles (DDGS), pulp
X	Total cultivable land surface of the farm
X_r	Available irrigated land area of the farm
w_f	Weight of farm
rot_coeff	Rotational coefficient
dec_surf	Decoupling surface
wt_j	Water requirement for crop *j*
wt_f	Water capacity of farm
$\mathrm{w}t_t$	Total water quantity of the region
$tr_{eth\ wir}$	Transformation rate from wheat to ethanol
$tr_{eth\ sbt}$	Transformation rate from sugar beet to ethanol
$q_{eth\ base}$	Reference capacity of 35000 tonnes
CO_{2j}	Carbon dioxide emission from crop *j*

Decision variables:

x_j	Area cultivated by crop *j*
$q_{\{sbt,\ wir\}}$	Demand for sugar beet or wheat
$q_{\{eth\ wir,\ eth\ sbt\}}$	Quantity of ethanol produced from wheat or sugar-beet
$q_{\{eth,\ ddgs,\ plp\}}$	Total quantity of ethanol, DDGS or pulp produced in a year
tc_{ind}	Annual total cost of the industry
CO_{2agri}	Carbon dioxide emission in agricultural production
$CO_{2save\ farming}$	CO_2 emission saving in farming due to introduction of energy crops
$CO_{2eth\ agri}$	CO_2 emission in farming for feedstock production
$CO_{2transport}$	CO_2 emission in transportation of feedstock from farm to plant
CO_{2ind}	CO_2 emission in industrial process for ethanol production
$CO_{2\ gasoline}$	CO_2 emission from gasoline to be replaced by ethanol

Objective functions

1. Total economic surplus: The first objective function concerns the maximization of total profitand is expressed by the following relation:

$$Max\sum_{j=1}^{n}((p_j + s_j)y_j + sub_j - v_j)x_j + \sum_{k=1}^{t}((\alpha - \frac{\beta}{2}\Sigma w_f y_k x_k)y_k - v_k)x_k + p_{eth} * q_{eth} + p_{ddgs} * q_{ddgs} + p_{plp} * q_{plp} - tc_{ind} \qquad (1)$$

2. Total CO_2 saving: The second objective function concerns the maximization of the total amount of CO_2 emission that will be avoided due to production and use of bioethanol.

$$MaxCO_{2save\_far\min g} + CO_{2gasoline} \qquad (2)$$

Subject to resource constraints:

Land constraint: Cultivated area must not be exceed the total cultivable land area of the farm.

$$\sum_{j=1}^{n} x_j - x_{vik} \le X \qquad (3)$$

Irrigated land area constraints: Irrigated crops area must not be exceed 10% more as of the total irrigated land area of the farm in 2002.

$$\sum x_r \le 1.1 * X_r \qquad (4)$$

Irrigation constrained: Water demand of the farm must not be exceed to the water capacity (actual quantity) of the farm.

$$\sum wt_j * x_j \le wt_f \qquad (5)$$

Regional water constraint: Water demand for all farms of the region equal to the total water quantity of the region.

$$\sum f \sum wt_j * x_j = wt_t \qquad (6)$$

Subject to quota constraints:

Constraint on cotton, sugar-beet and tobacco area: Crop area must not be exceed areas cultivated cotton in 2002.

$$X_{crop} \le coeff * X_{crop2002} \qquad (7)$$

Subject to flexibility constraints:

Maize for fodder area constraint: Fodder maize cultivation area must not be exceed by three times of maize cultivated area for fodder in 2002.

$$x_{mzf} \le 3 * x_{mzf\,2002} \qquad (8)$$

Potato cultivation area constraints: Potato cultivation area must not be exceed 10% more as of the total potato cultivated area of the farm in 2002.

$$x_{pot} \le 1.1 * x_{pot2002} \qquad (9)$$

Tomato cultivation area constraints: Tomato cultivation area must not be exceed 10% more as of the total tomato cultivated area of the farm in 2002.

$$x_{tom} \leq 1.1 * x_{tom\,2002} \tag{10}$$

Subject to environmental and policy constraints:

Constraints on alfalfa rotation area: Alfalfa area must not be exceed rotational coefficient times total rotational cropped area.

$$x_{alf} \leq rot\_coeff * \sum x_{rot} \tag{11}$$

Environmental constraints: Rotational vetch cultivation must not be less than decoupling surface deduced by alfalfa and multiplied by obligatory percentage.

$$x_{vik} \geq obligatorypercentage * (dec\_surf - x_{alf}) \tag{12}$$

Subject to biomass demand and supply constraints:

Wheat (sugar-beet) supply constraint: Wheat (sugar-beet) demand by the industry must not be exceed the total supply of wheat (sugar-beet).

$$q_{wir} \leq \sum f \sum w * y_{wir} * x_{wir} \tag{13}$$

$$q_{sbt} \leq \sum f \sum w * y_{sbt} * x_{sbt} \tag{14}$$

Balance constraints:

Total quantity of ethanol will be equal to the sum of quantity ethanol produced from wheat and quantity ethanol produced from sugar beet.

$$q_{eth} = q_{eth\_wir} + q_{eth\_sbt} = tr_{eth\_wir} * q_{wir} + tr_{eth\_sbt} * q_{sbt} \tag{15}$$

Total quantity of DDGS will be equal to the demand of wheat multiplied by transformation rate from wheat to DDGS.

$$q_{ddgs} = tr_{ddgs\_wir} * q_{wir} \tag{16}$$

Total quantity of pulp will be equal to the demand of sugar beet multiplied by transformation rate from sugar beet to pulp.

$$q_{plp} = tr_{plp\_sbt} * q_{sbt} \tag{17}$$

Total quantity of CO_2 emission in agriculture will be equal to the sum of quantity CO_2 emission from all crops.

$$CO_{2agri} = \sum f \sum CO_{2j} x_j \tag{18}$$

Quantity of CO_2 emission in agriculture for ethanol production is equal to the sum of quantity CO_2 emission from sugar beet and wheat.

$$CO_{2eth\_agri} = \sum f \sum CO_{2sbt} x_{sbt} + \sum f \sum CO_{2wir} x_{wir} \tag{19}$$

Quantity of CO_2 emission for transportation of feedstock for ethanol production is equal to the sum of quantity CO_2 emission for transportation of sugar beet and wheat.

$$CO_{2transport} = CO_{2tran\_sbt} + CO_{2tran\_wir} \tag{20}$$

Quantity of CO_2 emission in industry is equal to the sum of quantity CO_2 emissions for processing of sugar beet and wheat.

$$CO_{2ind} = CO_{2q_{eth\_sbt}} + CO_{2q_{eth\_wir}} \tag{21}$$

Total CO_2 emission for ethanol is equal to the sum of quantity CO_2 emission from sugar beet and irrigated wheat production and their industrial processing for ethanol production.

$$CO_{2eth\_tot} = CO_{2eth\_agri} + CO_{2transport} + CO_{2ind} \tag{22}$$

<u>Industry technical constraints:</u>

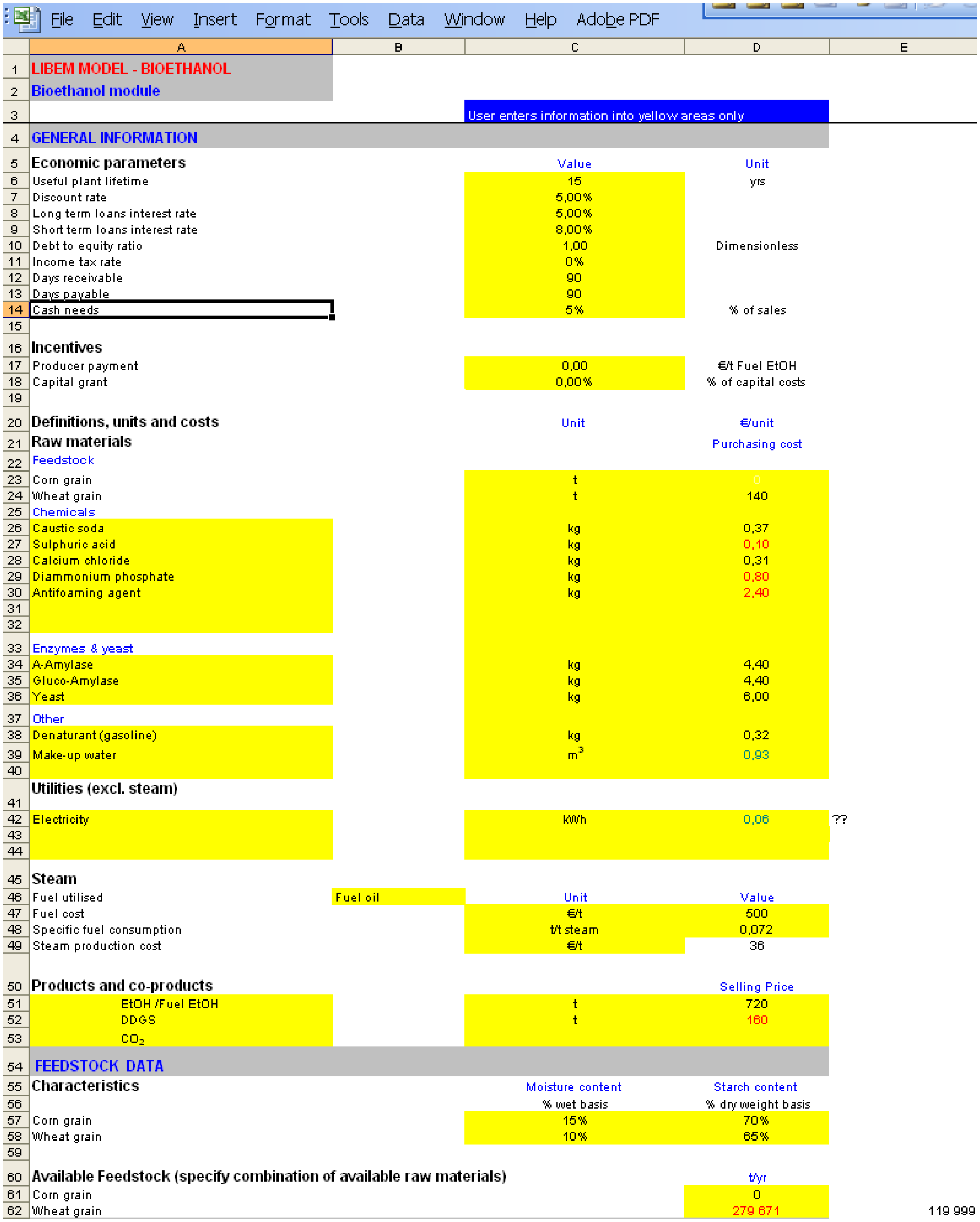
Total capital cost is derived from expected capacity divided by reference capacity (35 000 t) exponent by scale factor (0.61) and multiplied by reference investment cost (12.4 M Euro) and accumulated other investment cost factor (3.41).

$$TotalCapitalCost = 3.41 \cdot \left(q_{eth} / q_{eth\_base}\right)^{0.61} \cdot 12.4 \tag{23}$$

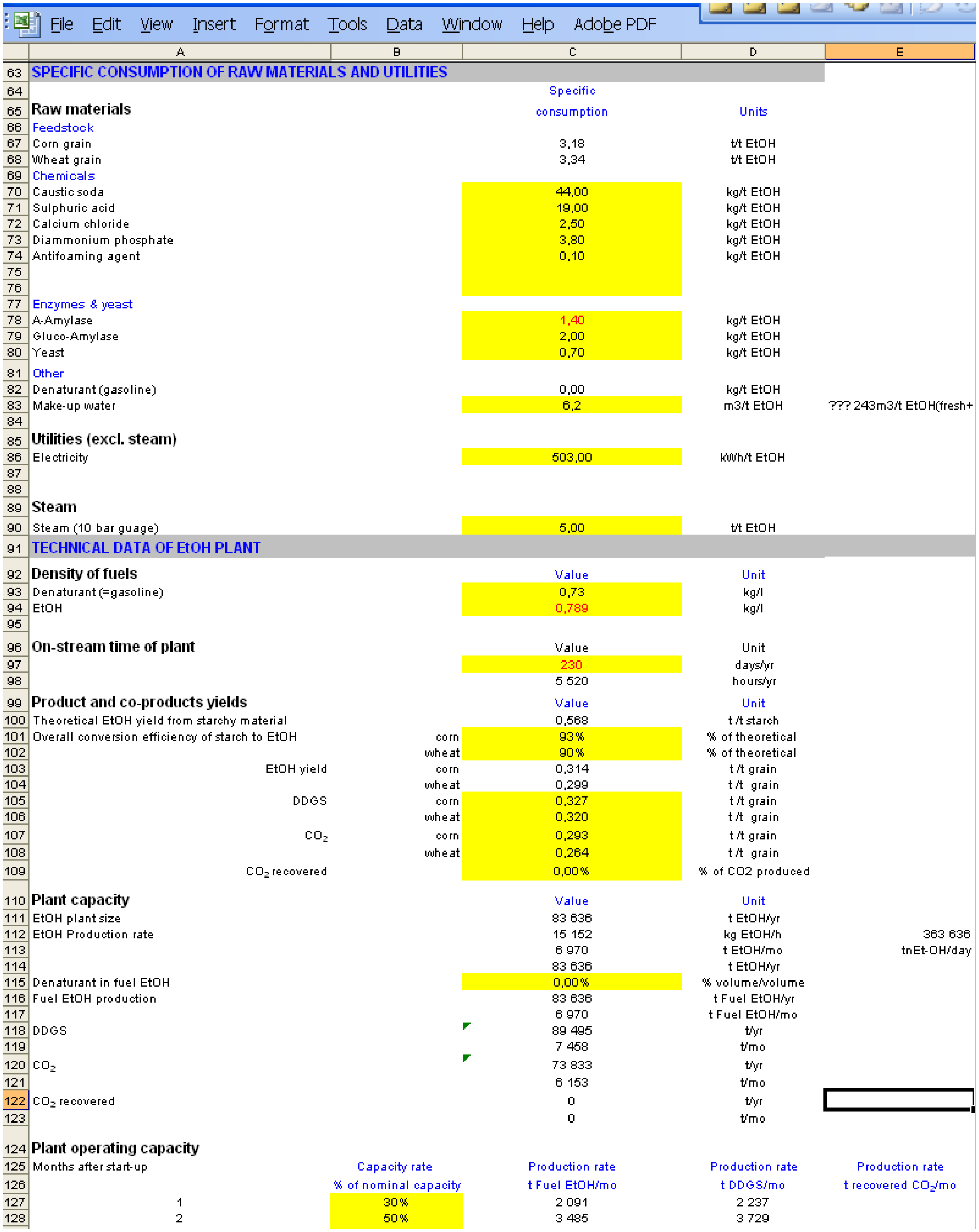
Plant capacity constraint: Annual capacity of ethanol production of the plant (size of the plant) assumed to be between 10000 and 120000 ton.

$$10000 \le q_{eth} \le 120000 \tag{24}$$

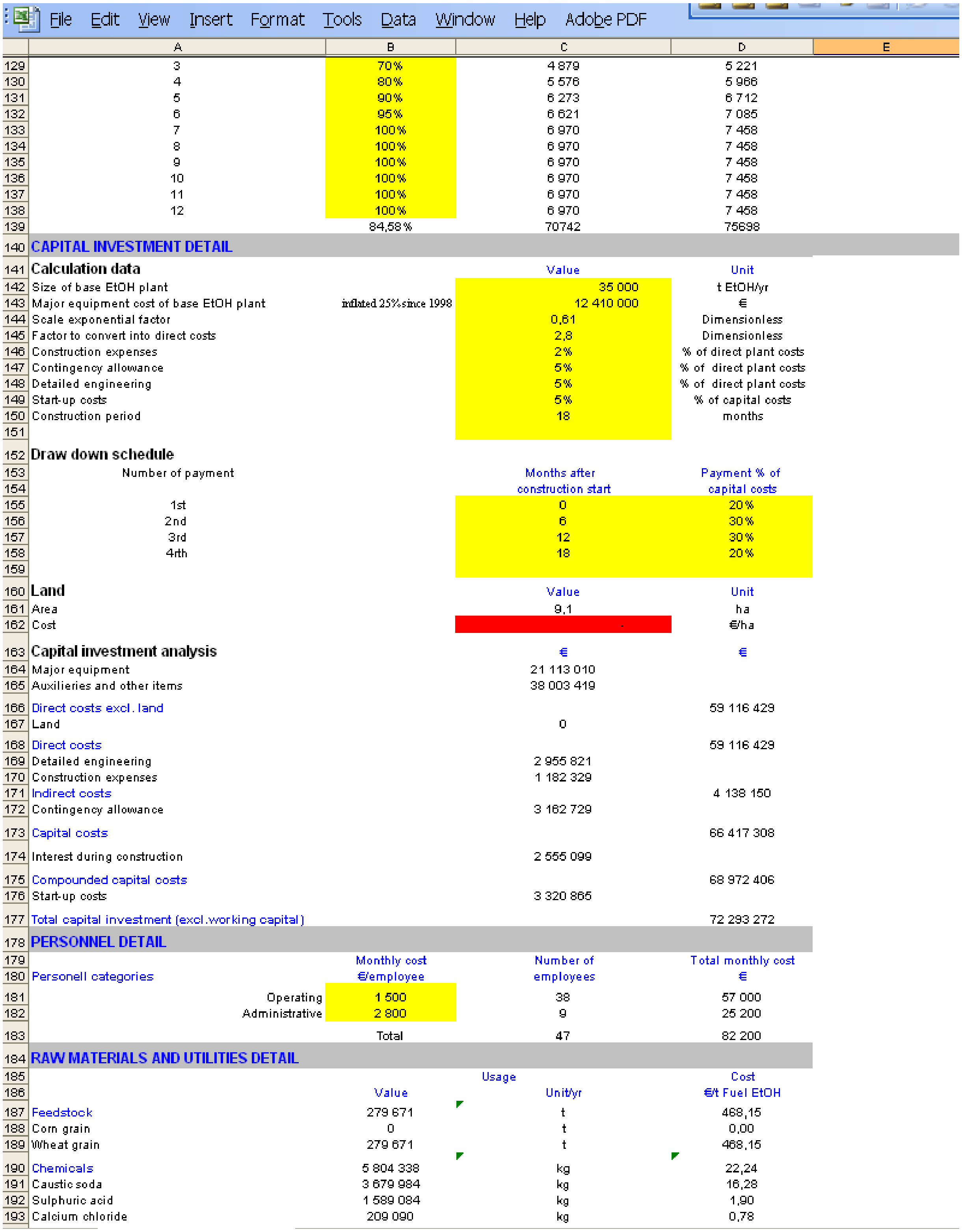
APPENDIX VII: LIBEM Model



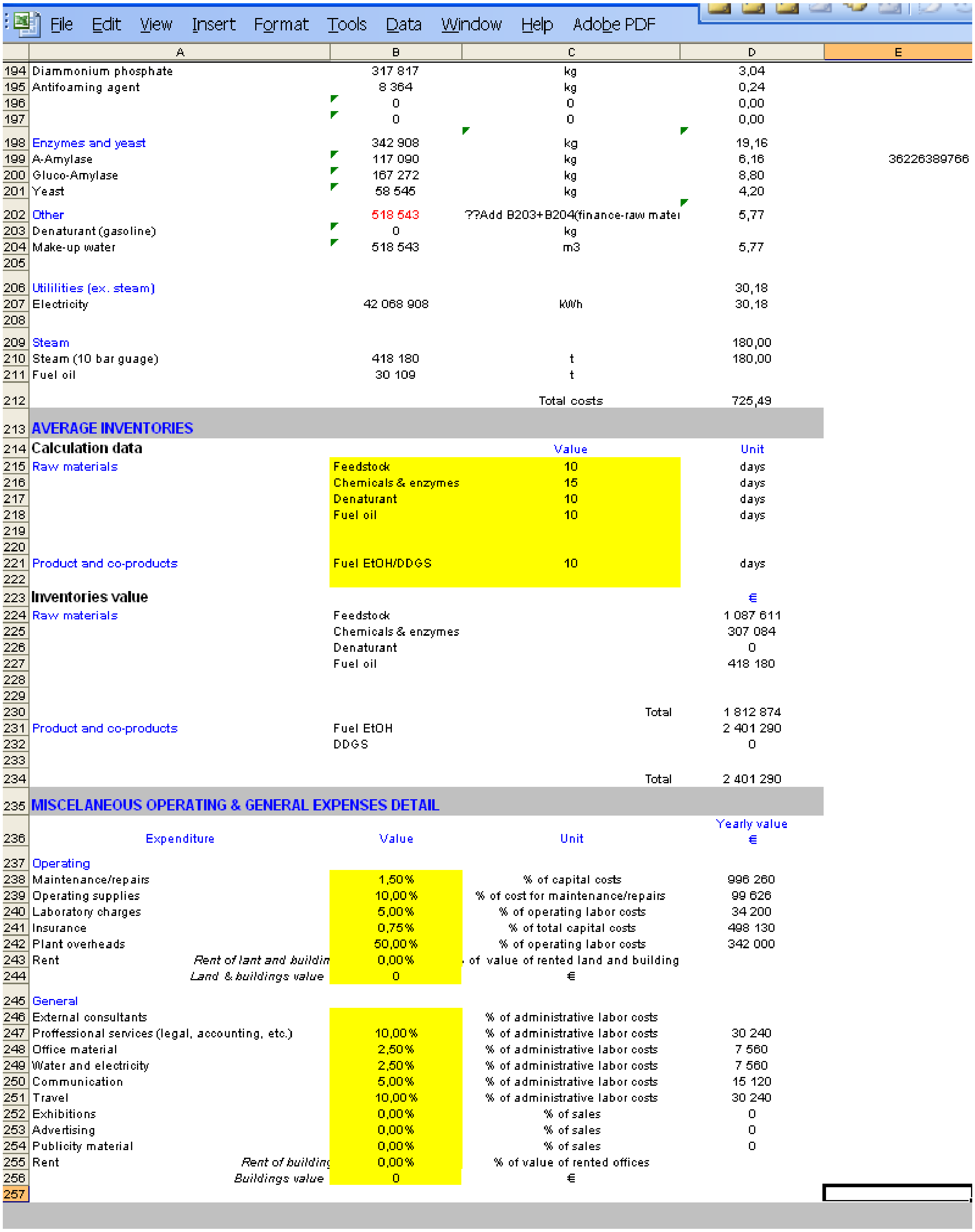
	A	B	C	D	E
1	LIBEM MODEL - BIOETHANOL				
2	Bioethanol module				
3			User enters information into yellow areas only		
4	GENERAL INFORMATION				
5	Economic parameters		Value	Unit	
6	Useful plant lifetime		15	yrs	
7	Discount rate		5,00%		
8	Long term loans interest rate		5,00%		
9	Short term loans interest rate		8,00%		
10	Debt to equity ratio		1,00	Dimensionless	
11	Income tax rate		0%		
12	Days receivable		90		
13	Days payable		90		
14	Cash needs		5%	% of sales	
15					
16	Incentives				
17	Producer payment		0,00	€/t Fuel EtOH	
18	Capital grant		0,00%	% of capital costs	
19					
20	Definitions, units and costs		Unit	€/unit	
21	Raw materials			Purchasing cost	
22	Feedstock				
23	Corn grain		t	0	
24	Wheat grain		t	140	
25	Chemicals				
26	Caustic soda		kg	0,37	
27	Sulphuric acid		kg	0,10	
28	Calcium chloride		kg	0,31	
29	Diammonium phosphate		kg	0,80	
30	Antifoaming agent		kg	2,40	
31					
32					
33	Enzymes & yeast				
34	A-Amylase		kg	4,40	
35	Gluco-Amylase		kg	4,40	
36	Yeast		kg	6,00	
37	Other				
38	Denaturant (gasoline)		kg	0,32	
39	Make-up water		m^3	0,93	
40					
41	Utilities (excl. steam)				
42	Electricity		kWh	0,06	??
43					
44					
45	Steam				
46	Fuel utilised	Fuel oil	Unit	Value	
47	Fuel cost		€/t	500	
48	Specific fuel consumption		t/t steam	0,072	
49	Steam production cost		€/t	36	
50	Products and co-products			Selling Price	
51	EtOH /Fuel EtOH		t	720	
52	DDGS		t	160	
53	CO_2				
54	FEEDSTOCK DATA				
55	Characteristics		Moisture content	Starch content	
56			% wet basis	% dry weight basis	
57	Corn grain		15%	70%	
58	Wheat grain		10%	65%	
59					
60	Available Feedstock (specify combination of available raw materials)			t/yr	
61	Corn grain			0	
62	Wheat grain			279 671	119 999



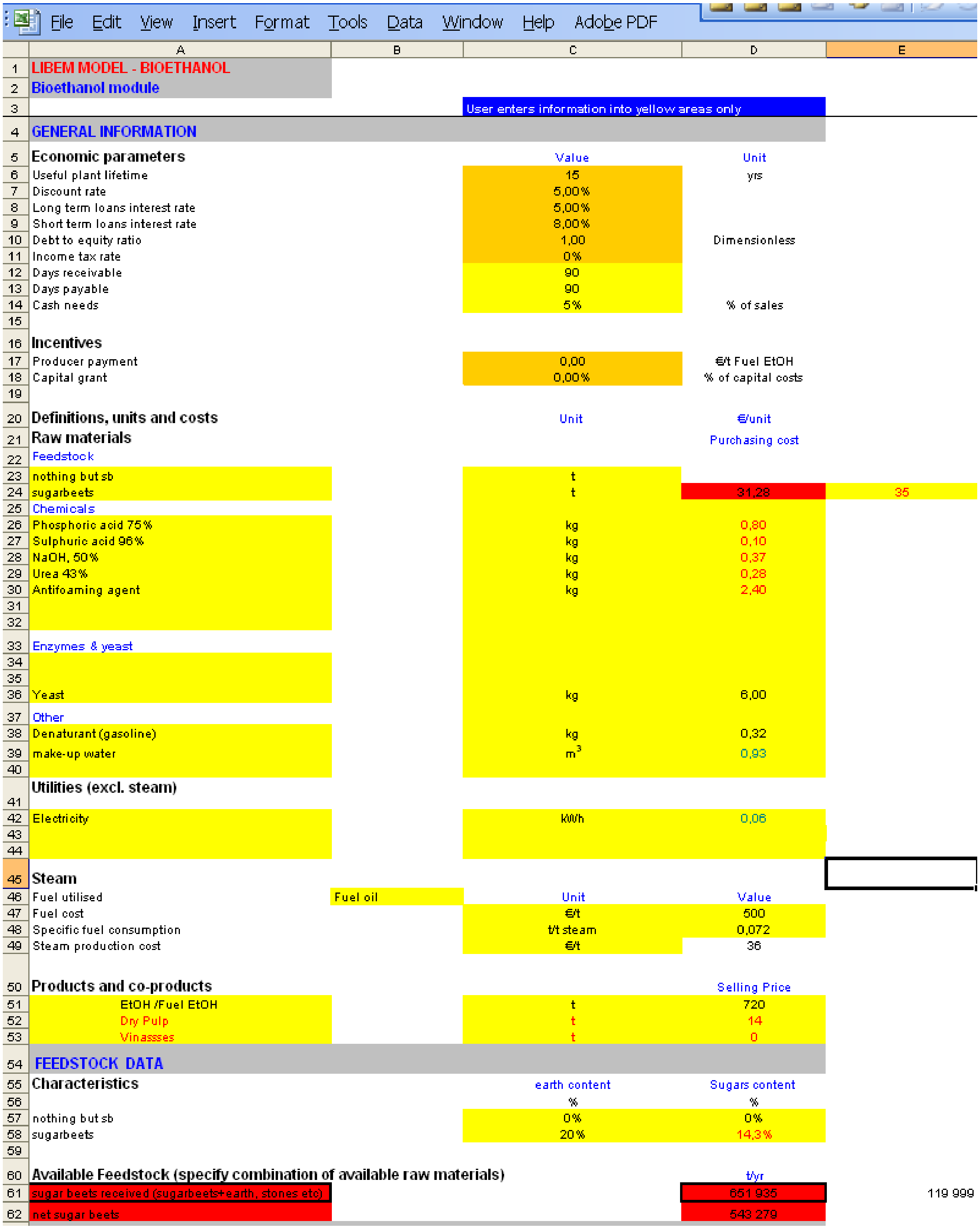
	A	B	C	D	E
63	SPECIFIC CONSUMPTION OF RAW MATERIALS AND UTILITIES				
64			Specific		
65	**Raw materials**		consumption	Units	
66	Feedstock				
67	Corn grain		3,18	t/t EtOH	
68	Wheat grain		3,34	t/t EtOH	
69	Chemicals				
70	Caustic soda		44,00	kg/t EtOH	
71	Sulphuric acid		19,00	kg/t EtOH	
72	Calcium chloride		2,50	kg/t EtOH	
73	Diammonium phosphate		3,80	kg/t EtOH	
74	Antifoaming agent		0,10	kg/t EtOH	
75					
76					
77	Enzymes & yeast				
78	A-Amylase		1,40	kg/t EtOH	
79	Gluco-Amylase		2,00	kg/t EtOH	
80	Yeast		0,70	kg/t EtOH	
81	Other				
82	Denaturant (gasoline)		0,00	kg/t EtOH	
83	Make-up water		6,2	m3/t EtOH	??? 243m3/t EtOH(fresh+
84					
85	**Utilities (excl. steam)**				
86	Electricity		503,00	kWh/t EtOH	
87					
88					
89	**Steam**				
90	Steam (10 bar guage)		5,00	t/t EtOH	
91	TECHNICAL DATA OF EtOH PLANT				
92	**Density of fuels**		Value	Unit	
93	Denaturant (=gasoline)		0,73	kg/l	
94	EtOH		0,789	kg/l	
95					
96	**On-stream time of plant**		Value	Unit	
97			230	days/yr	
98			5 520	hours/yr	
99	**Product and co-products yields**		Value	Unit	
100	Theoretical EtOH yield from starchy material		0,568	t /t starch	
101	Overall conversion efficiency of starch to EtOH	corn	93%	% of theoretical	
102		wheat	90%	% of theoretical	
103	EtOH yield	corn	0,314	t /t grain	
104		wheat	0,299	t /t grain	
105	DDGS	corn	0,327	t /t grain	
106		wheat	0,320	t /t grain	
107	CO_2	corn	0,293	t /t grain	
108		wheat	0,264	t /t grain	
109	CO_2 recovered		0,00%	% of CO2 produced	
110	**Plant capacity**		Value	Unit	
111	EtOH plant size		83 636	t EtOH/yr	
112	EtOH Production rate		15 152	kg EtOH/h	363 636
113			6 970	t EtOH/mo	tnEt-OH/day
114			83 636	t EtOH/yr	
115	Denaturant in fuel EtOH		0,00%	% volume/volume	
116	Fuel EtOH production		83 636	t Fuel EtOH/yr	
117			6 970	t Fuel EtOH/mo	
118	DDGS		89 495	t/yr	
119			7 458	t/mo	
120	CO_2		73 833	t/yr	
121			6 153	t/mo	
122	CO_2 recovered		0	t/yr	
123			0	t/mo	
124	**Plant operating capacity**				
125	Months after start-up	Capacity rate	Production rate	Production rate	Production rate
126		% of nominal capacity	t Fuel EtOH/mo	t DDGS/mo	t recovered CO_2/mo
127	1	30%	2 091	2 237	
128	2	50%	3 485	3 729	



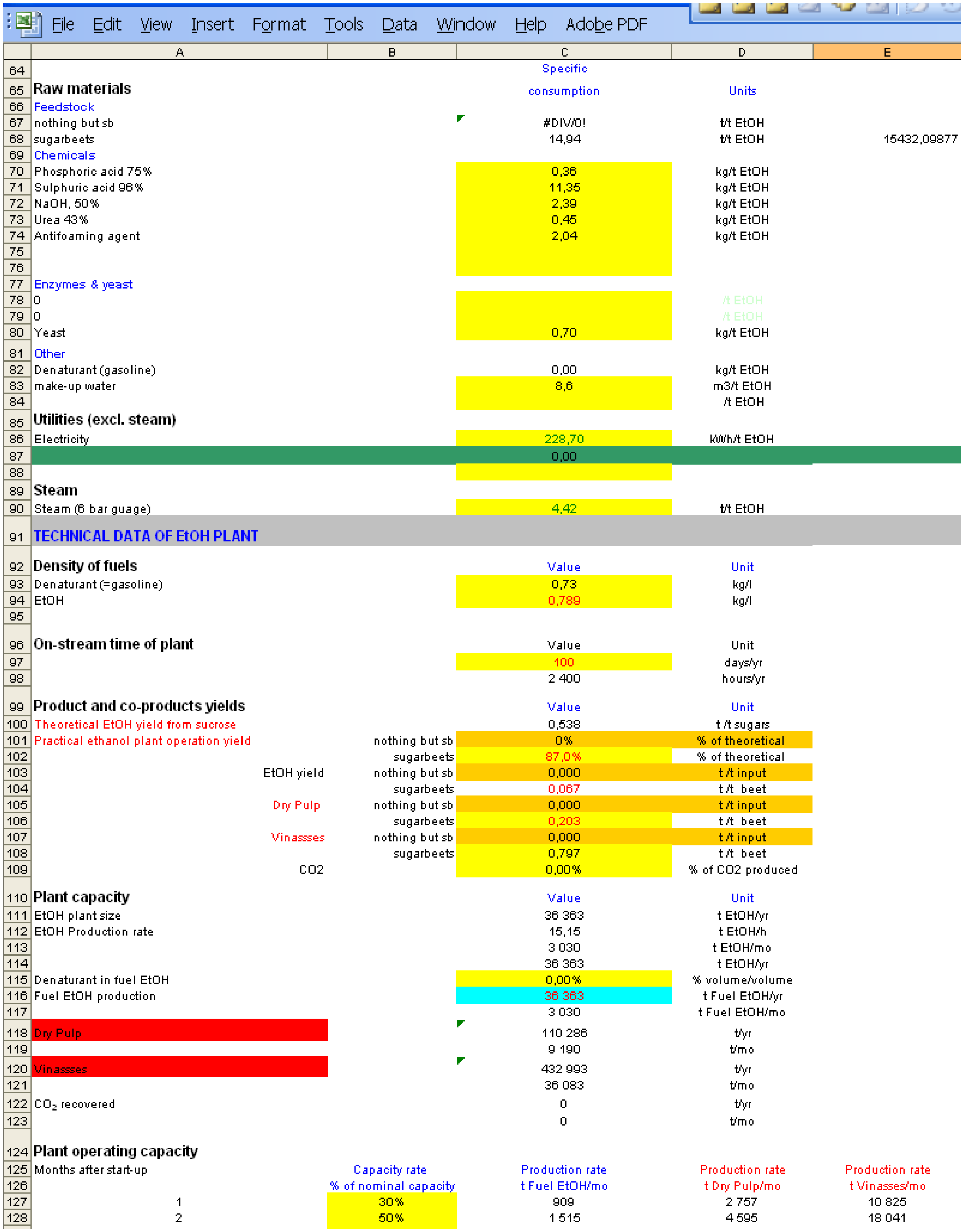
	A	B	C	D	E
129	3	70%	4 879	5 221	
130	4	80%	5 576	5 966	
131	5	90%	6 273	6 712	
132	6	95%	6 621	7 085	
133	7	100%	6 970	7 458	
134	8	100%	6 970	7 458	
135	9	100%	6 970	7 458	
136	10	100%	6 970	7 458	
137	11	100%	6 970	7 458	
138	12	100%	6 970	7 458	
139		84,58%	70742	75698	
140	**CAPITAL INVESTMENT DETAIL**				
141	**Calculation data**		Value	Unit	
142	Size of base EtOH plant		35 000	t EtOH/yr	
143	Major equipment cost of base EtOH plant	inflated 25% since 1998	12 410 000	€	
144	Scale exponential factor		0,61	Dimensionless	
145	Factor to convert into direct costs		2,8	Dimensionless	
146	Construction expenses		2%	% of direct plant costs	
147	Contingency allowance		5%	% of direct plant costs	
148	Detailed engineering		5%	% of direct plant costs	
149	Start-up costs		5%	% of capital costs	
150	Construction period		18	months	
151					
152	**Draw down schedule**				
153	Number of payment		Months after	Payment % of	
154			construction start	capital costs	
155	1st		0	20%	
156	2nd		6	30%	
157	3rd		12	30%	
158	4rth		18	20%	
159					
160	**Land**		Value	Unit	
161	Area		9,1	ha	
162	Cost		-	€/ha	
163	**Capital investment analysis**		€	€	
164	Major equipment		21 113 010		
165	Auxilieries and other items		38 003 419		
166	Direct costs excl. land			59 116 429	
167	Land		0		
168	Direct costs			59 116 429	
169	Detailed engineering		2 955 821		
170	Construction expenses		1 182 329		
171	Indirect costs			4 138 150	
172	Contingency allowance		3 162 729		
173	Capital costs			66 417 308	
174	Interest during construction		2 555 099		
175	Compounded capital costs			68 972 406	
176	Start-up costs		3 320 865		
177	Total capital investment (excl.working capital)			72 293 272	
178	**PERSONNEL DETAIL**				
179		Monthly cost	Number of	Total monthly cost	
180	Personell categories	€/employee	employees	€	
181	Operating	1 500	38	57 000	
182	Administrative	2 800	9	25 200	
183		Total	47	82 200	
184	**RAW MATERIALS AND UTILITIES DETAIL**				
185			Usage	Cost	
186		Value	Unit/yr	€/t Fuel EtOH	
187	Feedstock	279 671	t	468,15	
188	Corn grain	0	t	0,00	
189	Wheat grain	279 671	t	468,15	
190	Chemicals	5 804 338	kg	22,24	
191	Caustic soda	3 679 984	kg	16,28	
192	Sulphuric acid	1 589 084	kg	1,90	
193	Calcium chloride	209 090	kg	0,78	



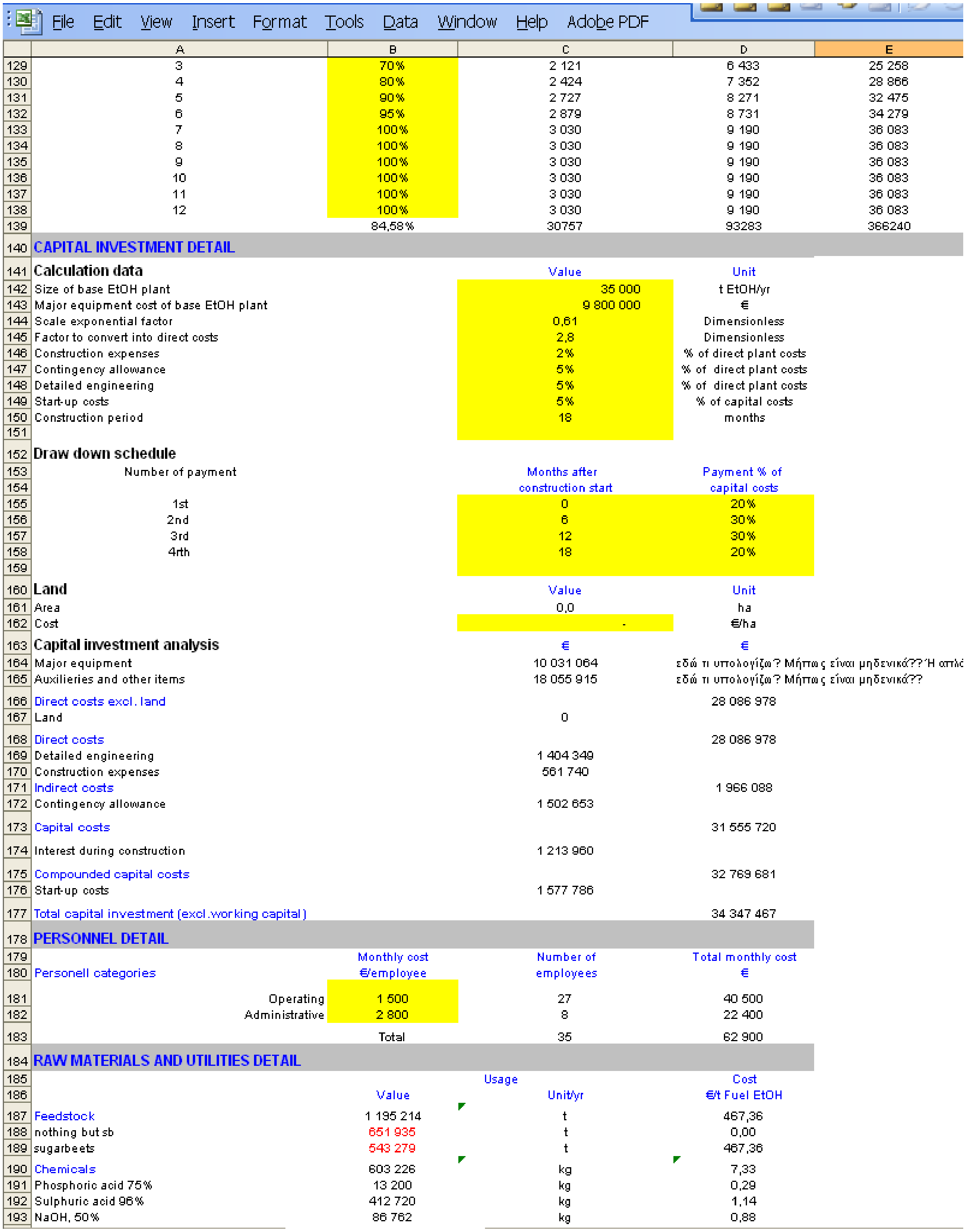
	A	B	C	D	E
194	Diammonium phosphate	317 817	kg	3,04	
195	Antifoaming agent	8 364	kg	0,24	
196		0	0	0,00	
197		0	0	0,00	
198	Enzymes and yeast	342 908	kg	19,16	
199	A-Amylase	117 090	kg	6,16	36226389766
200	Gluco-Amylase	167 272	kg	8,80	
201	Yeast	58 545	kg	4,20	
202	Other	518 543	??Add B203+B204(finance-raw mater	5,77	
203	Denaturant (gasoline)	0	kg		
204	Make-up water	518 543	m3	5,77	
205					
206	Utililities (ex. steam)			30,18	
207	Electricity	42 068 908	kWh	30,18	
208					
209	Steam			180,00	
210	Steam (10 bar guage)	418 180	t	180,00	
211	Fuel oil	30 109	t		
212			Total costs	725,49	
213	**AVERAGE INVENTORIES**				
214	**Calculation data**		Value	Unit	
215	Raw materials	Feedstock	10	days	
216		Chemicals & enzymes	15	days	
217		Denaturant	10	days	
218		Fuel oil	10	days	
219					
220					
221	Product and co-products	Fuel EtOH/DDGS	10	days	
222					
223	**Inventories value**			€	
224	Raw materials	Feedstock		1 087 611	
225		Chemicals & enzymes		307 084	
226		Denaturant		0	
227		Fuel oil		418 180	
228					
229					
230			Total	1 812 874	
231	Product and co-products	Fuel EtOH		2 401 290	
232		DDGS		0	
233					
234			Total	2 401 290	
235	**MISCELANEOUS OPERATING & GENERAL EXPENSES DETAIL**				
236	Expenditure	Value	Unit	Yearly value €	
237	Operating				
238	Maintenance/repairs	1,50%	% of capital costs	996 260	
239	Operating supplies	10,00%	% of cost for maintenance/repairs	99 626	
240	Laboratory charges	5,00%	% of operating labor costs	34 200	
241	Insurance	0,75%	% of total capital costs	498 130	
242	Plant overheads	50,00%	% of operating labor costs	342 000	
243	Rent *Rent of lant and buildin*	0,00%	of value of rented land and building		
244	*Land & buildings value*	0	€		
245	General				
246	External consultants		% of administrative labor costs		
247	Proffessional services (legal, accounting, etc.)	10,00%	% of administrative labor costs	30 240	
248	Office material	2,50%	% of administrative labor costs	7 560	
249	Water and electricity	2,50%	% of administrative labor costs	7 560	
250	Communication	5,00%	% of administrative labor costs	15 120	
251	Travel	10,00%	% of administrative labor costs	30 240	
252	Exhibitions	0,00%	% of sales	0	
253	Advertising	0,00%	% of sales	0	
254	Publicity material	0,00%	% of sales	0	
255	Rent *Rent of building*	0,00%	% of value of rented offices		
256	*Buildings value*	0	€		
257					



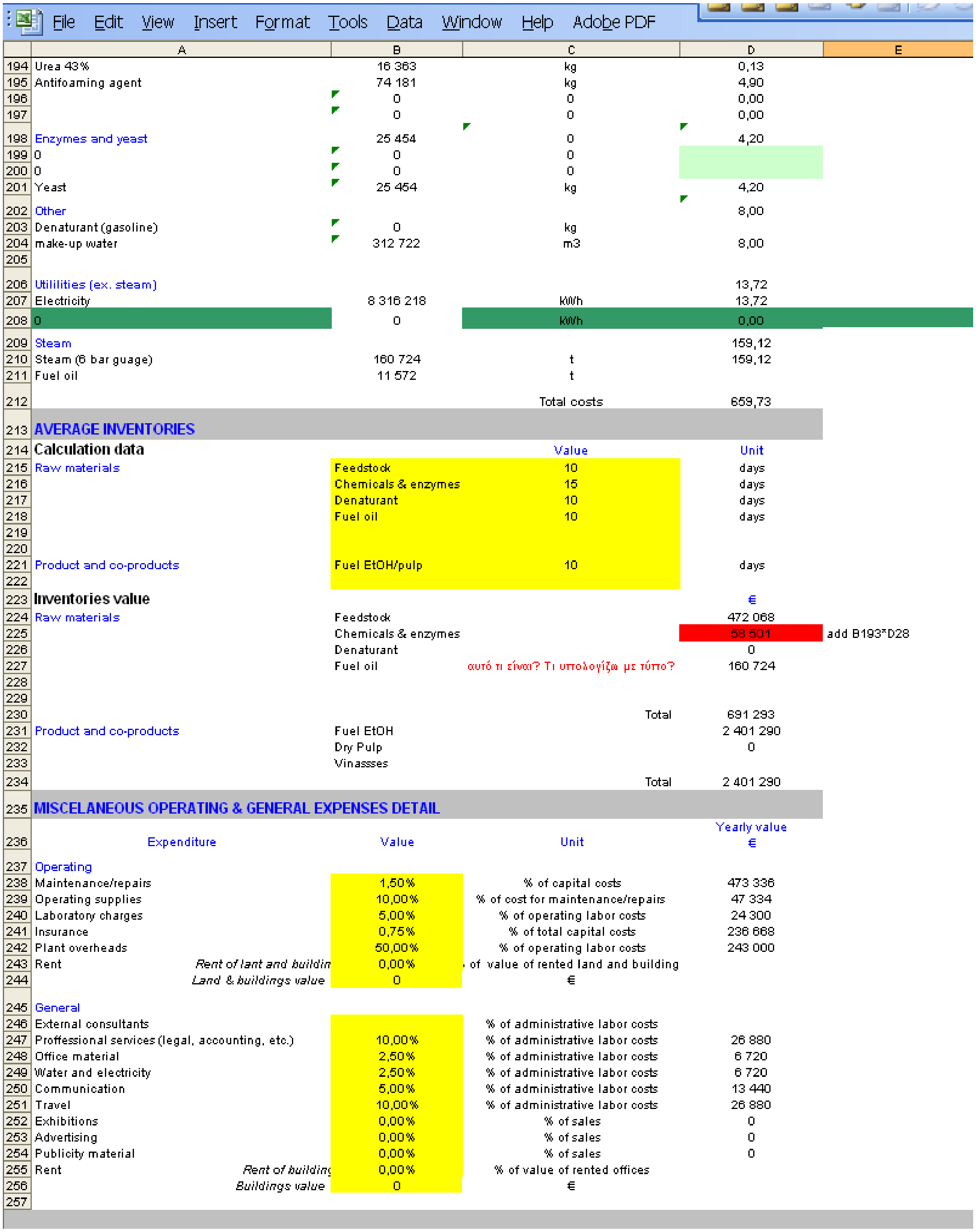
	A	B	C	D	E
1	LIBEM MODEL - BIOETHANOL				
2	Bioethanol module				
3			User enters information into yellow areas only		
4	GENERAL INFORMATION				
5	Economic parameters		Value	Unit	
6	Useful plant lifetime		15	yrs	
7	Discount rate		5,00%		
8	Long term loans interest rate		5,00%		
9	Short term loans interest rate		8,00%		
10	Debt to equity ratio		1,00	Dimensionless	
11	Income tax rate		0%		
12	Days receivable		90		
13	Days payable		90		
14	Cash needs		5%	% of sales	
15					
16	Incentives				
17	Producer payment		0,00	€/t Fuel EtOH	
18	Capital grant		0,00%	% of capital costs	
19					
20	Definitions, units and costs		Unit	€/unit	
21	Raw materials			Purchasing cost	
22	Feedstock				
23	nothing but sb		t		
24	sugarbeets		t	31,28	35
25	Chemicals				
26	Phosphoric acid 75%		kg	0,80	
27	Sulphuric acid 96%		kg	0,10	
28	NaOH, 50%		kg	0,37	
29	Urea 43%		kg	0,28	
30	Antifoaming agent		kg	2,40	
31					
32					
33	Enzymes & yeast				
34					
35					
36	Yeast		kg	6,00	
37	Other				
38	Denaturant (gasoline)		kg	0,32	
39	make-up water		m^3	0,93	
40					
41	Utilities (excl. steam)				
42	Electricity		kWh	0,06	
43					
44					
45	Steam				
46	Fuel utilised	Fuel oil	Unit	Value	
47	Fuel cost		€/t	500	
48	Specific fuel consumption		t/t steam	0,072	
49	Steam production cost		€/t	36	
50	Products and co-products			Selling Price	
51	EtOH /Fuel EtOH		t	720	
52	Dry Pulp		t	14	
53	Vinassses		t	0	
54	FEEDSTOCK DATA				
55	Characteristics		earth content	Sugars content	
56			%	%	
57	nothing but sb		0%	0%	
58	sugarbeets		20%	14,3%	
59					
60	Available Feedstock (specify combination of available raw materials)			t/yr	
61	sugar beets received (sugarbeets+earth, stones etc)			651 935	119 999
62	net sugar beets			543 279	



	A	B	C	D	E
64			Specific		
65	**Raw materials**		consumption	Units	
66	Feedstock				
67	nothing but sb		#DIV/0!	t/t EtOH	
68	sugarbeets		14,94	t/t EtOH	15432,09877
69	Chemicals				
70	Phosphoric acid 75%		0,36	kg/t EtOH	
71	Sulphuric acid 98%		11,35	kg/t EtOH	
72	NaOH, 50%		2,39	kg/t EtOH	
73	Urea 43%		0,45	kg/t EtOH	
74	Antifoaming agent		2,04	kg/t EtOH	
75					
76					
77	Enzymes & yeast				
78	0			/t EtOH	
79	0			/t EtOH	
80	Yeast		0,70	kg/t EtOH	
81	Other				
82	Denaturant (gasoline)		0,00	kg/t EtOH	
83	make-up water		8,6	m3/t EtOH	
84				/t EtOH	
85	**Utilities (excl. steam)**				
86	Electricity		228,70	kWh/t EtOH	
87			0,00		
88					
89	**Steam**				
90	Steam (6 bar guage)		4,42	t/t EtOH	
91	**TECHNICAL DATA OF EtOH PLANT**				
92	**Density of fuels**		Value	Unit	
93	Denaturant (=gasoline)		0,73	kg/l	
94	EtOH		0,789	kg/l	
95					
96	**On-stream time of plant**		Value	Unit	
97			100	days/yr	
98			2 400	hours/yr	
99	**Product and co-products yields**		Value	Unit	
100	Theoretical EtOH yield from sucrose		0,538	t /t sugars	
101	Practical ethanol plant operation yield	nothing but sb	0%	% of theoretical	
102		sugarbeets	87,0%	% of theoretical	
103	EtOH yield	nothing but sb	0,000	t /t input	
104		sugarbeets	0,067	t /t beet	
105	Dry Pulp	nothing but sb	0,000	t /t input	
106		sugarbeets	0,203	t /t beet	
107	Vinassses	nothing but sb	0,000	t /t input	
108		sugarbeets	0,797	t /t beet	
109	CO2		0,00%	% of CO2 produced	
110	**Plant capacity**		Value	Unit	
111	EtOH plant size		36 363	t EtOH/yr	
112	EtOH Production rate		15,15	t EtOH/h	
113			3 030	t EtOH/mo	
114			36 363	t EtOH/yr	
115	Denaturant in fuel EtOH		0,00%	% volume/volume	
116	Fuel EtOH production		36 363	t Fuel EtOH/yr	
117			3 030	t Fuel EtOH/mo	
118	Dry Pulp		110 286	t/yr	
119			9 190	t/mo	
120	Vinassses		432 993	t/yr	
121			36 083	t/mo	
122	CO_2 recovered		0	t/yr	
123			0	t/mo	
124	**Plant operating capacity**				
125	Months after start-up	Capacity rate	Production rate	Production rate	Production rate
126		% of nominal capacity	t Fuel EtOH/mo	t Dry Pulp/mo	t Vinasses/mo
127	1	30%	909	2 757	10 825
128	2	50%	1 515	4 595	18 041



	A	B	C	D	E
129	3	70%	2 121	6 433	25 258
130	4	80%	2 424	7 352	28 866
131	5	90%	2 727	8 271	32 475
132	6	95%	2 879	8 731	34 279
133	7	100%	3 030	9 190	36 083
134	8	100%	3 030	9 190	36 083
135	9	100%	3 030	9 190	36 083
136	10	100%	3 030	9 190	36 083
137	11	100%	3 030	9 190	36 083
138	12	100%	3 030	9 190	36 083
139		84,58%	30757	93283	366240
140	**CAPITAL INVESTMENT DETAIL**				
141	**Calculation data**		Value	Unit	
142	Size of base EtOH plant		35 000	t EtOH/yr	
143	Major equipment cost of base EtOH plant		9 800 000	€	
144	Scale exponential factor		0,61	Dimensionless	
145	Factor to convert into direct costs		2,8	Dimensionless	
146	Construction expenses		2%	% of direct plant costs	
147	Contingency allowance		5%	% of direct plant costs	
148	Detailed engineering		5%	% of direct plant costs	
149	Start-up costs		5%	% of capital costs	
150	Construction period		18	months	
151					
152	**Draw down schedule**				
153	Number of payment		Months after	Payment % of	
154			construction start	capital costs	
155	1st		0	20%	
156	2nd		6	30%	
157	3rd		12	30%	
158	4rth		18	20%	
159					
160	**Land**		Value	Unit	
161	Area		0,0	ha	
162	Cost		-	€/ha	
163	**Capital investment analysis**		€	€	
164	Major equipment		10 031 064	εδώ τι υπολογίζω? Μήπως είναι μηδενικά?? Ή απλά	
165	Auxilieries and other items		18 055 915	εδώ τι υπολογίζω? Μήπως είναι μηδενικά??	
166	Direct costs excl. land			28 086 978	
167	Land		0		
168	Direct costs			28 086 978	
169	Detailed engineering		1 404 349		
170	Construction expenses		561 740		
171	Indirect costs			1 966 088	
172	Contingency allowance		1 502 653		
173	Capital costs			31 555 720	
174	Interest during construction		1 213 960		
175	Compounded capital costs			32 769 681	
176	Start-up costs		1 577 786		
177	Total capital investment (excl.working capital)			34 347 467	
178	**PERSONNEL DETAIL**				
179		Monthly cost	Number of	Total monthly cost	
180	Personell categories	€/employee	employees	€	
181	Operating	1 500	27	40 500	
182	Administrative	2 800	8	22 400	
183		Total	35	62 900	
184	**RAW MATERIALS AND UTILITIES DETAIL**				
185			Usage	Cost	
186		Value	Unit/yr	€/t Fuel EtOH	
187	Feedstock	1 195 214	t	467,36	
188	nothing but sb	651 935	t	0,00	
189	sugarbeets	543 279	t	467,36	
190	Chemicals	603 226	kg	7,33	
191	Phosphoric acid 75%	13 200	kg	0,29	
192	Sulphuric acid 96%	412 720	kg	1,14	
193	NaOH, 50%	86 762	kg	0,88	



	A	B	C	D	E
194	Urea 43%	16 363	kg	0,13	
195	Antifoaming agent	74 181	kg	4,90	
196		0	0	0,00	
197		0	0	0,00	
198	Enzymes and yeast	25 454	0	4,20	
199	0	0	0		
200	0	0	0		
201	Yeast	25 454	kg	4,20	
202	Other			8,00	
203	Denaturant (gasoline)	0	kg		
204	make-up water	312 722	m3	8,00	
205					
206	Utililities (ex. steam)			13,72	
207	Electricity	8 316 218	kWh	13,72	
208	0	0	kWh	0,00	
209	Steam			159,12	
210	Steam (6 bar guage)	160 724	t	159,12	
211	Fuel oil	11 572	t		
212			Total costs	659,73	
213	**AVERAGE INVENTORIES**				
214	**Calculation data**		Value	Unit	
215	Raw materials	Feedstock	10	days	
216		Chemicals & enzymes	15	days	
217		Denaturant	10	days	
218		Fuel oil	10	days	
219					
220					
221	Product and co-products	Fuel EtOH/pulp	10	days	
222					
223	**Inventories value**			€	
224	Raw materials	Feedstock		472 068	
225		Chemicals & enzymes		58 501	add B193*D28
226		Denaturant		0	
227		Fuel oil	αυτό τι είναι? Τι υπολογίζω με τύπο?	160 724	
228					
229					
230			Total	691 293	
231	Product and co-products	Fuel EtOH		2 401 290	
232		Dry Pulp		0	
233		Vinassses			
234			Total	2 401 290	
235	**MISCELANEOUS OPERATING & GENERAL EXPENSES DETAIL**				
236	Expenditure	Value	Unit	Yearly value €	
237	Operating				
238	Maintenance/repairs	1,50%	% of capital costs	473 336	
239	Operating supplies	10,00%	% of cost for maintenance/repairs	47 334	
240	Laboratory charges	5,00%	% of operating labor costs	24 300	
241	Insurance	0,75%	% of total capital costs	236 668	
242	Plant overheads	50,00%	% of operating labor costs	243 000	
243	Rent *Rent of lant and buildin*	0,00%	of value of rented land and building		
244	*Land & buildings value*	0	€		
245	General				
246	External consultants		% of administrative labor costs		
247	Proffessional services (legal, accounting, etc.)	10,00%	% of administrative labor costs	26 880	
248	Office material	2,50%	% of administrative labor costs	6 720	
249	Water and electricity	2,50%	% of administrative labor costs	6 720	
250	Communication	5,00%	% of administrative labor costs	13 440	
251	Travel	10,00%	% of administrative labor costs	26 880	
252	Exhibitions	0,00%	% of sales	0	
253	Advertising	0,00%	% of sales	0	
254	Publicity material	0,00%	% of sales	0	
255	Rent *Rent of building*	0,00%	% of value of rented offices		
256	*Buildings value*	0	€		
257					

APPENDIX VIII: GAMS code

```
set
fe all farms /1*344/, re regions /470, 480/
c crop /sfw, drw, wir, mze, tob, cotd, cot, cots, pot, sbt, tom, mzf, alf,
crf, oil, cyn, vik/
cc(c) crop /sfw, drw, wir, mze, tob, cotd, cot, cots, pot, sbt, tom, mzf,
crf, oil, cyn, vik/
cer(c) cereals  /sfw, drw, wir, mze/
c1(c) /drw, mze/
c2(c) /tob, cot/
rot(c) crops for rotation alfalfa /mze, mzf, tob, sbt, cot, tom, wir/
dec(c) crops receiving decoupled payment /sfw, drw, mze, tob, cotd, cot,
wir/
r(c) irrigated crops /tob, cot, mze, pot, sbt, tom, mzf, alf, cots, wir/
r_cot(c) irrig minus cotton /tob, mze, pot, sbt, tom, mzf, alf, wir/
f(fe)  selected farms to run the model /1*344/
f470(fe) /1*336/, f480(fe) /337*344/
f41(fe) KARDITSA /1*119/, f42(fe) LARISSA /120*265/, f43(fe) MAGNESIA
/266*283/
f44(fe) TRIKALA /284*336/, f6(fe) PHTHIOTIDA /337*344/

*f(fe)  selected farms to run the model /f418,f419, f421, f709, f969/

test working /reg,nomos, farm, weight, top, type, emm, mae, meo, mea/;

scalars
alpha constant coeff linear demand for alfalfa in c /0.18/
beta  slope linear demand for alfalfa /0.00000000006/

parameter prix(f, c) prices calc using sales.txt
ap(c) average prices
/sfw  0.13, drw 0.145 , mze  0.16, mzf   0.03, alf 0.16, cotd 0.25,   tob
2.82
cot  0.88, tom 0.1, pot 0.2, sbt 0.039, oil 0.18, cyn 0.06/
ay(c) average yield
/sfw  300, drw 320, mze 1020, mzf  5900, alf 1500, cotd 150,  tob  220, cot
340
pot 2700, tom 6000, sbt 6000, vik 280, cyn 1300/
;
$include .\input_teliko1.gms

parameter co2eq_only(c)
/sfw 593.7289, drw 593.7289, wir 614.4289, mze  1767.898136, mzf
1767.898136, alf 716.9594436, cotd 1400,   tob 1573.41144
cot 1502.146654, tom 1687.26144, pot 1699.212504, sbt 869.33305 /
```

```
parameter co2eq(c) all gases including N2O emissions
/sfw 996.6589, drw 996.6589, wir 1017.3589, mze  2855.402136, mzf
2855.402136, alf 896.9348436, cotd 2000,   tob  2159.49144
cot 2172.882654, tom 2273.34144, pot 2234.824504, sbt 1227.49305/
parameter co2eq_plus_trans(c) all gases including N2O emissions
/sfw 1002.43, drw 1002.43, wir 1030.82, mze  2876.56, mzf   2951.57, alf
925.785, cotd 2000,   tob  2178.73
cot 2179.61, tom 2331.04, pot 2304.07, sbt 1356.36/
origq_co2eq initial observed level base year, origq_n2o initial observed
level base year;
origq_co2eq=sum((f,c), co2eq_only(c)*info(f,'weight')*surf(f,c)/1000);
origq_n2o=sum((f,c), (co2eq(c)-
co2eq_only(c))*info(f,'weight')*surf(f,c)/1000);

*calculate prices if any

prix(f,c)$(surf(f,c) and yield(f,c))=sales(f,c)/(yield(f,c)*surf(f,c));
prix(f,'cotd')=prix(f, 'cot');

*Selected area defined by crops receiving decoupled payment (index:dec)

parameter decsurf(f) decoupling surface ; decsurf(f)=sum(dec, surf(f,dec));
*cynara related to durum wheat
yield(f,'cyn')=5*yield(f,'drw');
*alfalfa yield cannot be more than 2500
yield(f,'alf')$(yield(f,'alf') gt 2500)=2500;
*test for dry cotton
parameter yieldrycot(f) dry cotton yield, manlab(f) manual labour;
yieldrycot(f)= yield(f, 'cot'); manlab(f)=varcost(f, 'rela');
display yieldrycot, manlab;
*historical data to define water quantities available at the farm level
parameter wtcap(f) actual water demand in cubic meters;
wtcap(f)=200*surf(f,'cotd')+150*surf(f, 'cots')+400*surf(f,
'cot')+600*surf(f, 'mze')+700*surf(f, 'tob')
+700*surf(f, 'pot')+800*surf(f, 'sbt')+800*surf(f, 'tom') +600*surf(f,
'mzf')+700*surf(f, 'alf');

parameter orig_totwat initial observed level water quantities;
orig_totwat = sum(f, info(f,'weight')*(200*surf(f,'cotd')+150*surf(f,
'cots')+400*surf(f, 'cot')+600*surf(f, 'mze')
+700*surf(f, 'tob')+700*surf(f, 'pot')+800*surf(f, 'sbt')+800*surf(f,
'tom') +600*surf(f, 'mzf')+700*surf(f, 'alf')));

parameter subs1(f,c) basic cereal compensation allocated to durum wheat;
subs1(f, 'drw')$surf(f,'drw')=subs(f, 'sfw')/surf(f,'drw');
subs(f, c)$(surf(f,c))=subs(f,c)/surf(f,c);
```

```
*total area subs to drw : specific plus basic
subs(f, 'drw')=subs(f,'drw')+subs1(f, 'drw');

subs(f, 'sfw')$surf(f,'sfw')=15; subs(f, c)$(surf(f,c) eq 0)=0;
*adjust for subs per kg
parameter subkg(f,c) subsidies per kg;
subkg(f, c)$(surf(f,c) and yield(f,c))=sub(f,c)/(yield(f,c)*surf(f,c));
*Average 2000-2002
subkg(f, 'cot')=0.90*subkg(f, 'cot'); subkg(f, 'cotd')=subkg(f, 'cot');
*fix problem with irrigated crops that exceed irrigated land per farm
parameter rirrig(f) revised irrigated land per farm, r_cot_land(f) irrig
minus cotton,  cotd(f) surface dry cotton
; rirrig(f)=sum(r, surf(f, r)); r_cot_land(f)=sum(r_cot, surf(f,r_cot))-
surf(f, 'irr');

*switch observed values to dry cotton if dryland plus low yields of cotton
cotd(f)$(r_cot_land(f) gt 0)=surf(f, 'cot');
surf(f, 'cotd')$(surf(f,'cot') lt 250)=cotd(f); surf(f, 'cot')$cotd(f)=0;
yield(f,'cotd')$surf(f,'cot')=0*yield(f,'cot');

parameter vcost(f,c) variable cost               ;
vcost(f,c)=vc2002(f,c);   vcost(f, 'cotd')=55.5; vcost(f, 'cots')=25;
vcost(f, 'vik')=15; vcost(f, 'cyn')=36;
vcost(f,'alf')$(vcost(f,'alf') gt 110)=108; vcost(f, 'wir')=41;

parameter salesha(f,c) sales per ha, margha(f, c) margin per ha
totsubs(f) histo farm subs, cheque(f) histo farm subs, subpart(f) ratio of
subs to farm margin, totsubs_agri total amount of agricultural subsidy;
salesha(f,c)$surf(f,c)=(prix(f,c)+subkg(f,c))*yield(f,c);
margha(f,c)$surf(f,c)=(prix(f,c)+subkg(f,c))*yield(f,c)+subs(f,c)-
(vcost(f,c));
totsubs(f)=sum(c, surf(f,c)*(subkg(f,c)*yield(f,c)+subs(f,c)));
cheque(f)=
0.98*(
0.90*sum(c, subs(f,c)*surf(f,c))+
0.98*subkg(f,'tob')*yield(f,'tob')*surf(f,'tob')
+96.6*(surf(f,'cotd')+surf(f,'cot'))
                );
subpart(f)=totsubs(f)/sum(c, margha(f,c));
totsubs_agri = sum(f, totsubs(f));
display salesha, margha, totsubs_agri;

parameter surface(f) total surface applied, surfirr(f); surface(f)=sum(c,
surf(f,c));
surfirr(f)=surf(f,'irr');
```

```
*cultivated decoupling area
parameter dec_surf(f) surface obtaining decoupling payment subject to oblig
rotation
check_str(f) average decoupled per stremma, oblig_percent percentage for
cross compliance
rot_coeff rotation alfalfa;
dec_surf(f)=sum(dec, surf(f,dec));  check_str(f)=totsubs(f)/dec_surf(f);
oblig_percent=0.20;
rot_coeff=1.5; display dec_surf;
```

INDUSTRY MODEL WITHOUT BIOGAS (configuration 1)

```
Parameters pw timi wheat/110/, pt timi teytlwn/32/
weth tranformation wheat to ethanol/0.299/, sbeth transformation sbt to
ethanol/0.067/
dd transformation wheat to ddgs/0.32/, plp transformation sbt to
poulpa/0.2/
elecw_eth  kWh per t EtOH wheat /503/, elecb_eth  kWh per t EtOH sbeet
/228.7/
preth timi eyhanol /800/, prdd timi ddgs/160/, prplp timi poulpas/14/, pel
price electr /0.06/
p_oil price fuel oil euro per ton /500/, spec_f_steam specific fuel
consumption for steam /0.072/
steam_weth specif steam per ton eth wheat /5/, steam_beth specif steam per
ton eth beet /4.42/
cchw cost chem ana t eth apo wheat/47.17/,  ccht cost chem ana t eth apo
sbt/19.53/
scalecoeff scale coefficient /0.61/,  base_invcost investment cost basis
/12410000/
basecap base capacity in tons /35000/, maxq maximum quantity /130000/, minq
/10000/

celw cost elec ana t eth apo wheat, celt cost elec ana t eth apo sbt
cstw cost steam ana t eth apo wheat, cstt cost steam ana t eth apo sbt;

celw=pel*elecw_eth; celt=pel*elecb_eth;
cstw=p_oil*spec_f_steam*steam_weth; cstt=p_oil*spec_f_steam*steam_beth;

positive variable
x(f,c)
free variables
totgm, totalf, totgmnl
wirdem paragwgi wheat, sbtdem paragwgi sbt, Qeth_tot synoliki paragwgi
ethanol
Qeth_wir paragwgi eth apo sitari, Qeth_sbt paragwgi eth apo teytla
Qddgs paragwgi DDGS, Qpoulpa paragwgi poulpas
```

```
fst prwtes yles cost,  totcost synoliko kostos, prof profit, synolo total
surplus, synolo2000 surplus previousCAP
chem cost ximikwn kai enzymwn, elec electr cost, steam steam cost
lab_man ergasia paragwgi, maint maintenance cost, oper leitourgika cost,
lab_adm ergasia dioikitiki
ins asfaleia, gener genika eksoda, exter ekswterika cost, office eksoda
grafeiou, elwat fws nero
trav taksidia cost, com epikoinwnia cost,
totcapcost total capital cost, capcost_ann annual capital cost,  ratcap
ratio capacity div by 35000;

equations
capitalcost tot cost calc, capannual annualized cost
land(f)   land constraint, irrig(f)  irrigated land
flexcotd(f) dry cotton, flexcot(f) inertia when cot, flexmzf(f) inertia
when ensiromeno mz
flexcer(f)   flexibility cereals, flextob(f) flexibility tobacco
flexpot(f) flex potato, decpot(f) potato only in non epileximi ektasi
demsgb(f)  sb contracts, demtom(f)  tom contracts, demcyn demand total
cynara
demcyn450,demcyn470, demsyn480, rotatalf(f) alfalfa rotation, water_alf(f)
demand constraint for alfalfa
vikoblig(f) obligatory env rotation, objectif  objective function base case
totmargnl non linear total margin, aggalf aggregate alfalfa production

posotita_sitari paragwgi potistikou sitariou, posotita_teytla paragwgi
teytlwn

quant_eth_w posotita ethanol apo wheat, quant_eth_sbt posotita ethanol apo
sbt
quant_eth total posotita ethanol, quant_dd posotita ddgs, quant_plp
posotita poulpas
ximika, electricity, atmos, labor1 ergasia manufacturing, syntirisi,
operations, labor2 ergasia administrative
insurance, general, external, grafika, diafora reyma kai nero, travel,
communication,
feedstock, totalcost
capacity1 capacity constraint 1, capacity2 capacity constraint 2,
production imerisia paragwgi
kerdos kerdos ergostasiou, stoxos enwsi dyo montelwn, stoxosCAP2000
previous CAP;
;
land(f).. sum(c, x(f,c))-x(f,'vik')=l=surface(f);
irrig(f).. sum(r, x(f,r))=l=1.1*rirrig(f);
flexcer(f)$surf(f,'cer')..  sum(cer, x(f,cer))=l=1000*surf(f,'cer');
flexcot(f)..  x(f,'cot')+x(f,'cotd')=l=surf(f,'cot')+surf(f,'cotd');
```

```
flexcotd(f)..  x(f,'cotd')=e=surf(f,'cotd');
flexmzf(f)..  x(f,'mzf')=l=3*surf(f,'mzf');
flextob(f).. x(f,'tob')=l=surf(f,'tob');
decpot(f).. x(f,'pot')=l=surface(f)-decsurf(f);
flexpot(f).. x(f,'pot')=l=1.1*surf(f,'pot');
demsgb(f).. x(f,'sbt')=l=surf(f,'sbt');
demtom(f).. x(f,'tom')=l=1.1*surf(f,'tom');
demcyn.. sum(f, info(f,'weight')*yield(f, 'wir')*x(f, 'wir'))=g=0;
rotatalf(f).. x(f, 'alf')=l= rot_coeff*sum(rot, x(f,rot));
water_alf(f).. 200*x(f,'wir')+200*x(f,'cotd')+150*x(f, 'cots')+400*x(f,
'cot')+600*x(f, 'mze')+700*x(f, 'tob')+700*x(f, 'pot')
+800*x(f, 'sbt')+800*x(f, 'tom') +600*x(f, 'mzf')+700*x(f,
'alf')=l=1*wtcap(f);
vikoblig(f).. x(f,'vik')-oblig_percent*(dec_surf(f)-x(f,'alf'))=g=0;
objectif..  sum((f,c), info(f,'weight')*margha(f,c)*x(f,c))=e=totgm;
aggalf.. sum(f, info(f,'weight')*yield(f,'alf')*x(f,'alf'))=e=totalf;
totmargnl.. sum((f,cc), info(f,'weight')*margha(f,cc)*x(f,cc))
         +sum(f, info(f,'weight')*((alpha-(beta/2)*totalf)*yield(f,'alf')-
vcost(f,'alf'))*x(f,'alf'))=e=totgmnl;

posotita_sitari.. wirdem=l=(sum(f, info(f,'weight')*yield(f, 'wir')*x(f,
'wir')))/1000;

posotita_teytla.. sbtdem=l=(sum(f, info(f,'weight')*yield(f, 'sbt')*x(f,
'sbt')))/1000;
quant_eth_w.. Qeth_wir=e=weth*wirdem;
quant_eth_sbt.. Qeth_sbt=e=sbeth*sbtdem;
quant_eth.. Qeth_tot=e=weth*wirdem + sbeth*sbtdem;
quant_dd.. Qddgs=e=dd*wirdem;
quant_plp.. Qpoulpa=e=plp*sbtdem;
feedstock.. fst=e=pw*wirdem + pt*sbtdem;
ximika.. chem=e=cchw*Qeth_wir + ccht*Qeth_sbt;
electricity.. elec=e=celw*Qeth_wir + celt*Qeth_sbt;
atmos.. steam=e=cstw*Qeth_wir + cstt*Qeth_sbt;
labor1.. lab_man=e=612282.438+(2445.818*(Qeth_tot**0.49))-
(317272.68*(Qeth_tot**0.05));
syntirisi.. maint=e=990.172*(Qeth_tot**0.61)+(1.969*(Qeth_tot**0.84));
operations.. oper=e=99.017*(Qeth_tot**0.61)+(0.197*(Qeth_tot**0.84));
labor2.. lab_adm=e=-736287.216+(592242.336*(Qeth_tot**0.05));
insurance.. ins=e=495.086*(Qeth_tot**0.61)+(0.938*(Qeth_tot**0.84));
general.. gener=e=49.509*(Qeth_tot**0.61)+(0.099*(Qeth_tot**0.84));
external.. exter=e=-73628.722+(59224.234*(Qeth_tot**0.05));
grafika.. office=e=-18407.18+(14806.058*(Qeth_tot**0.05));
diafora.. elwat=e=-18407.18+(14806.058*(Qeth_tot**0.05));
travel.. trav=e=-73628.722+(59224.234*(Qeth_tot**0.05));
communication.. com=e=-36814.361+(29612.117*(Qeth_tot**0.05));
```

```
capitalcost..  totcapcost=e= 3.41*exp(scalecoeff*(log(Qeth_tot)-
log(basecap)));
capannual..   capcost_ann=e=totcapcost*base_invcost/((1-power((1+0.06),-
15))/0.06);
totalcost.. totcost=e=capcost_ann
+chem+elec+steam +lab_man
+maint+oper+lab_adm+ins
;
capacity1.. Qeth_tot =g= minq;
capacity2.. Qeth_tot =l= maxq;
production.. Qeth_wir/230 =e= Qeth_sbt/100;
kerdos.. prof=e=
prdd*Qddgs+prplp*Qpoulpa-totcost;
stoxosCAP2000.. synolo2000=e=prof+totgmnl;
stoxos.. synolo=e=prof+totgmnl;

file chec/.\param_lp.txt/; chec.pc=6; put chec; chec.nd=5;

options limrow=4,limcol=4; model essai/land, irrig, flexcotd, flexcot,
flexmzf, flextob
flexpot, demsgb, demtom, rotatalf, water_alf, objectif
/;
option lp=cplex; solve essai using lp maximizing totgm;

parameter optq_co2eq optimal level base year, optq_n2o;
optq_co2eq=sum((f,c), co2eq_only(c)*info(f,'weight')*x.l(f,c)/1000);
optq_n2o=sum((f,c), (co2eq(c)-
co2eq_only(c))*info(f,'weight')*x.l(f,c)/1000);

parameter reaggsau really cultivated land, aggsau obs, aggasau actual total
sau cultivated, nlaggasau  nlp
aggosurf(c) agg obs surf per crop, aggsurf(c) agg crop cultivated,
nlaggsurf(c) agg crop cultivated nlp,
surfcult(f) surface really cultivated in 2002;
surfcult(f)=sum(c, surf(f,c));

*fix problem of fake unused land because of declared surface area exceeding
cultivated surface in 2002
aggsau=sum(f, info(f,'weight')*surf(f, 'sau')); reaggsau=sum(f,
info(f,'weight')*surfcult(f));
aggasau=sum((f,c), info(f,'weight')*x.l(f,c));
aggosurf(c)= sum(f, info(f,'weight')*surf(f,c)/1000);
aggsurf(c)= sum(f, info(f,'weight')*x.l(f,c)/1000);

options limrow=4,limcol=4; model essainl/land, irrig, flexcotd, flexcot,
flexmzf, flextob
```

```
flexpot, demsgb, demtom, rotatalf, water_alf, aggalf, totmargnl/;

option lp=cplex; solve essainl using nlp maximizing totgmnl;
nlaggsurf(c)= sum(f, info(f,'weight')*x.l(f,c)/1000);
nlaggasau=sum((f,c), info(f,'weight')*x.l(f,c));
parameter pricealf00; pricealf00=alpha-beta*totalf.l;

*CALCULATIONS AVERAGE VALUES
parameters
cy(fe,c) count, toty(c) number of f per c, avyd(c) mean global, avy(re,c)
regional
p(f,c) only positive prices, cp(f,c) count, totp(c) number of f per c,
avp(c) mean
k(f,c) only positive subkg, ck(f,c) count, totk(c) number of f per c,
avk(c) mean
su(f,c) only positive subs, cs(f,c) count, tots(c) number of f per c,
avs(c) mean
v(f,c) only positive vcost, cv(f,c) count, totv(c) number of f per c,
avv(c) mean
;
cy(f470,c)$yield(f470,c)=info(f470, 'weight'); toty(c)=sum(f470,
cy(f470,c));
avy("470",c)$toty(c)=sum(f470, info(f470, 'weight')*yield(f470,c))/toty(c);
cy(f480,c)$yield(f480,c)=info(f480, 'weight'); toty(c)=sum(f480,
cy(f480,c));
avy("480",c)$toty(c)=sum(f480, info(f480, 'weight')*yield(f480,c))/toty(c);
avyd(c)=sum(re, avy(re, c))/4; avyd('sfw')=290;
p(f,c)$prix(f,c)=prix(f,c); cp(f,c)$p(f,c)=1; totp(c)=sum(f, cp(f,c));
avp(c)$totp(c)=sum(f, prix(f,c))/totp(c); avp('cyn')=0.0;
k(f,c)$subkg(f,c)=subkg(f,c); ck(f,c)$k(f,c)=1; totk(c)=sum(f, ck(f,c));
avk(c)$totk(c)=sum(f, subkg(f,c))/totk(c);
su(f,c)$subs(f,c)=subs(f,c); cs(f,c)$su(f,c)=1; tots(c)=sum(f, cs(f,c));
avs(c)$tots(c)=sum(f, subs(f,c))/tots(c);
v(f,c)$vcost(f,c)=vcost(f,c); cv(f,c)$v(f,c)=1; totv(c)=sum(f, cv(f,c));
avv(c)$totv(c)=sum(f, vcost(f,c))/totv(c);

parameter price(f, c) all prices, yiel(*, c) obs yield plus projected for
those no, varc(f,c) same purpose;
yiel(f470,c)$(yield(f470,c) eq 0)=avy("470",c);
yiel(f480,c)$(yield(f480,c) eq 0)=avy("480",c);
yiel(f480,'sfw')=avy("470",'sfw');yield(f,c)=yield(f,c)+yiel(f,c);
price(f,c)$(prix(f,c) eq 0)=avp(c); price(f,c)=prix(f,c)+price(f,c);
price(f, 'alf')=.15;
varc(f,c)$(vcost(f,c) eq 0)=avv(c); vcost(f,c)=varc(f,c)+vcost(f,c);
subs(f,c)=0; subs(f, 'drw')=10; subs(f, 'mze')=10;
```

```
subkg(f,c)=0; subkg(f,'tom')=0.035; subs(f,'cotd')=55;
subs(f,'cot')=subs(f,'cotd'); subs(f,'cots')=subs(f,'cotd');
yield(f, 'wir')=1.5*yield(f,'cot');
subs(f, 'wir')=4.5;
price(f, 'sbt')=.0; price(f, 'wir')=.0;
subs(f,'sbt')=32; subs(f, 'sbt')=subs(f, 'sbt')+4.5;
margha(f,c)
=(price(f,c)+subkg(f,c))*yield(f,c)+subs(f,c)-vcost(f,c);

Qeth_tot.lo=1;
Qeth_sbt.lo=0.0001;

options limrow=4,limcol=4; model essai03/land, irrig, flexmzf, decpot,
flexpot, demsgb, demcyn, demtom, rotatalf
water_alf, objectif, aggalf, vikoblig, totmargnl/;
option lp=cplex; solve essai03 using nlp maximizing totgmnl;
parameters aggasau03,  aggsurf03 lp CAP2003, obj_essai03 obj value;
aggasau03=sum((f,c), info(f,'weight')*x.l(f,c)); aggsurf03(c)= sum(f,
info(f,'weight')*x.l(f,c)/1000);
obj_essai03=totgmnl.l;

parameter newCAP_nlpq_co2eq optimal level nlp new CAP without industry,
newCAP_nlpq_n2o;
parameter newCAP_nlp_trans_co2eq optimal level nlp new CAP without
industry;
newCAP_nlpq_co2eq=sum((f,c),
co2eq_only(c)*info(f,'weight')*x.l(f,c)/1000)/10;
newCAP_nlpq_n2o=sum((f,c), (co2eq(c)-
co2eq_only(c))*info(f,'weight')*x.l(f,c)/1000)/10;
newCAP_nlp_trans_co2eq=sum((f,c), (co2eq_plus_trans(c)-
co2eq(c))*info(f,'weight')*x.l(f,c)/1000)/10;

parameter newCAP_nlp_co2only optimal CO2 agric without N20,
newCAP_nlp_co2incn2o optimal CO2eq incl N20, newCAP_nlp_co2inctrans optimal
CO2eq incl N20 plus trans;
newCAP_nlp_co2only=sum((f,c),
co2eq_only(c)*info(f,'weight')*x.l(f,c)/1000)/10;
newCAP_nlp_co2incn2o=sum((f,c),
co2eq(c)*info(f,'weight')*x.l(f,c)/1000)/10;
newCAP_nlp_co2inctrans =sum((f,c),
co2eq_plus_trans(c)*info(f,'weight')*x.l(f,c)/1000)/10;
display   newCAP_nlp_co2only, newCAP_nlp_co2incn2o, newCAP_nlp_co2inctrans;

parameter  newCAP_nlp_totwat_no_eth optimal level nlp new CAP without
ethanol water quantity;
```

```
newCAP_nlp_totwat_no_eth=sum(f,
info(f,'weight')*(200*x.l(f,'cotd')+150*x.l(f, 'cots')+400*x.l(f,
'cot')+600*x.l(f, 'mze')
+700*x.l(f, 'tob')+700*x.l(f, 'pot')+800*x.l(f, 'sbt')+800*x.l(f, 'tom')
+600*x.l(f, 'mzf')+700*x.l(f, 'alf')));

model essainlp /
land, irrig, flexmzf, decpot, flexpot, demsgb, demcyn, demtom, rotatalf
water_alf, objectif, aggalf, vikoblig, totmargnl, posotita_sitari,
posotita_teytla
capitalcost, capannual, quant_eth_w, quant_eth_sbt, quant_eth, quant_dd,
quant_plp
ximika, electricity, atmos, labor1, syntirisi, operations, labor2
insurance, general, external, grafika, diafora, travel, communication,
totalcost, capacity1, capacity2, production, kerdos, stoxos
/;
```

***LOOP**

```
set s /1*1/;
parameter
elect_wir_ind electricity requirement in industrial process for wheat
ethanol(kWh per ton of ethanol)/503/
elect_sbt_ind electricity requirement in industrial process for sugarbeet
ethanol(kWh per ton of ethanol)/228.7/
fuel_oil_steam_wir fuel oil requirement for steam for ethanol pdn from
wheat (kg per ton of ethanol)/360/
fuel_oil_steam_sbt fuel oil requirement for steam for ethanol pdn from
sugar beet (kg per ton of ethanol)/318/
fuel_eff_eth fuel efficiency of ethanol compare to gasoline /0.8/
rCO2_gasoline CO2 emission rate from gasoline(kg CO2e per ton of
gasoline)/3152.29/
tax_gasoline rate of taxation on gasoline (Euro per ton (1ton=1356
liter*0.8))/1084.8/
CO2fuel_oil rate of CO2 emission from fuel oil (kg CO2 per kg) /3.45/
CO2elect rate of CO2 emission from electricity(kg CO2 per kWh) /0.618/
elect_in(s) electricity used in industrial process for ethanol (kWh),
elect_perton e per ton ethanol
fuel_oil_stm(s) fuel oil for steam for ethanol(kg), fuel_oil_stm_perton
CO2fuel_oil_stm_wir CO2 emission from fuel oil for steam in the industry
for wheat ethanol(kg)

daggasau, daggasau8 actual total sau cultivated after decoupling
daggsurf(c), daggsurf8(c) agg crop cultivated after dec, pricealf
tottax_gasoline(s) total amount of tax on gasoline (euro)
basefarm_surplus(s), obj_essainlp(s), obj_1(s)
```

```
matinp(s), labour(s), m_o_ins(s), uccost(s), ubiocost(s), uinpcost(s),
ulabcost(s), umoicost(s), tucost(s)
puccost(s), pubiocost(s), puinpcost(s), pulabcost(s), pumoicost(s),
usales(s), pusales(s), ubyprod(s), pubyprod(s), ppreth(s)

maxqeth(s) max eth plant capacity, priceth(s) price  range eth,
lbasefarm_surplus(s), lobj_essainlp(s), lobj_1(s), lobj_2(s), lobj_3(s)

lQty_wheat(s), ldual_wheat(s), lQty_beet(s), ldual_beet(s), lQeth(s),
lQethwh(s), lQethsb(s), lQddgs(s), lQpulp(s)
ltcost(s), lcc_annual(s)

globnlpq_co2eq optimal level nlp new CAP plus industry, globnlpq_n2o,
globnlp_trans_co2eq transport
diffco2(s) difference new CAP with and without ethanol, diff_ton
diffco2_tr(s) difference new CAP with and without ethanol incl transport
cost, diff_ton_tr

CO2_gas_perton, totCO2eth(s) total, CO2_perton, netCO2eth(s)
Qgasoline_rep(s) quantity gasoline(ton) to be replaced, CO2_gasoline(s)
quantity(kg) of CO2 emission using gasoline
cost_CO2save_perton(s) cost of CO2 emisson saving per ton

parameter  newCAP_nlp_totwat_with_eth optimal level nlp new CAP with
ethanol water quantity;
newCAP_nlp_totwat_with_eth=sum(f,
info(f,'weight')*(200*x.l(f,'cotd')+150*x.l(f, 'cots')+400*x.l(f,
'cot')+600*x.l(f, 'mze')
+700*x.l(f, 'tob')+700*x.l(f, 'pot')+800*x.l(f, 'sbt')+800*x.l(f, 'tom')
+600*x.l(f, 'mzf')+700*x.l(f, 'alf')));

display  orig_totwat, newCAP_nlp_totwat_no_eth, newCAP_nlp_totwat_with_eth;
;
           minq=110000;
loop (s,      minq=minq+10000;
options limrow=3,limcol=3; option nlp=conopt; solve essainlp using nlp
maximizing synolo;

maxqeth(s)=maxq; lobj_essainlp(s)=synolo.l; lobj_1(s)=prof.l/Qeth_tot.l;
lobj_2(s)=totgmnl.l; lobj_3(s)=prof.l;
lbasefarm_surplus(s)=(totgmnl.l-obj_essai03)/Qeth_tot.l;

lQty_wheat(s)=wirdem.l; ldual_wheat(s)=posotita_sitari.m;
lQty_beet(s)=sbtdem.l; ldual_beet(s)=posotita_teytla.m;
```

```
lQeth(s)=Qeth_tot.l; lQethwh(s)=Qeth_wir.l; lQethsb(s)=Qeth_sbt.l;
lQddgs(s)=Qddgs.l; lQpulp(s)=Qpoulpa.l;
ltcost(s)=totcost.l; lcc_annual(s)=capcost_ann.l;

matinp(s)=chem.l+elec.l+steam.l; labour(s)=lab_man.l+lab_adm.l;
m_o_ins(s)=maint.l+oper.l+ins.l;
uccost(s)=capcost_ann.l/Qeth_tot.l;
ulabcost(s)=labour(s)/Qeth_tot.l;
ubiocost(s)=(posotita_sitari.m*wirdem.l+posotita_teytla.m*sbtdem.l)/Qeth_to
t.l;
uinpcost(s)=matinp(s)/Qeth_tot.l;
umoicost(s)=m_o_ins(s)/Qeth_tot.l;
tucost(s)=uccost(s)+ubiocost(s)+uinpcost(s)+ulabcost(s)+umoicost(s);
puccost(s)=uccost(s)/tucost(s); pulabcost(s)=ulabcost(s)/tucost(s);
pubiocost(s)=ubiocost(s)/tucost(s); puinpcost(s)=uinpcost(s)/tucost(s);
pumoicost(s)=umoicost(s)/tucost(s);
ppreth(s)=preth/tucost(s);
ubyprod(s)=(prdd*Qddgs.l+prplp*Qpoulpa.l)/Qeth_tot.l;
pubyprod(s)=ubyprod(s)/tucost(s);
usales(s)=(preth*Qeth_tot.l+prdd*Qddgs.l+prplp*Qpoulpa.l)/Qeth_tot.l;
pusales(s)=usales(s)/tucost(s);

globnlpq_co2eq=sum((f,c), co2eq_only(c)*info(f,'weight')*x.l(f,c)/1000)/10;
globnlpq_n2o=sum((f,c), (co2eq(c)-
co2eq_only(c))*info(f,'weight')*x.l(f,c)/1000)/10;
globnlp_trans_co2eq = sum((f,c), (co2eq_plus_trans(c)-
co2eq(c))*info(f,'weight')*x.l(f,c)/1000)/10;
diffco2(s)= (globnlpq_co2eq+globnlpq_n2o)-
(newCAP_nlpq_co2eq+newCAP_nlpq_n2o);
diffco2_tr(s)= globnlp_trans_co2eq -  newCAP_nlp_trans_co2eq;

elect_in(s)=CO2elect*(elect_sbt_ind*Qeth_sbt.l+elect_wir_ind*Qeth_wir.l)/10
00;

fuel_oil_stm(s)=CO2fuel_oil*(fuel_oil_steam_sbt*Qeth_sbt.l+fuel_oil_steam_w
ir*Qeth_wir.l)/1000;
Qgasoline_rep(s)=Qeth_tot.l*fuel_eff_eth;
CO2_gasoline(s)=Qeth_tot.l*fuel_eff_eth*rCO2_gasoline/1000;
tottax_gasoline(s)=Qgasoline_rep(s)*tax_gasoline;
totCO2eth(s)=diffco2(s)+diffco2_tr(s)+elect_in(s)+fuel_oil_stm(s)-
CO2_gasoline(s);
cost_CO2save_perton(s)= tottax_gasoline(s)/totCO2eth(s);
Display   elect_in, fuel_oil_stm

);
```

```
put ' ', loop(s, put s.tl);  put/;
put ' ', loop(s, put maxqeth(s)); put/;
put 'results ethanol plant at the optimum' ,  put /;
put   ' Qty wheat', loop(s, put lQty_wheat(s)); put / ;
put   'dual price wheat', loop(s, put ldual_wheat(s)); put /;
put    'Qty sbt' , loop(s, put lQty_beet(s)); put /;
put  'dual price sugar beet',loop(s, put ldual_beet(s)) ;  put /;
put    'Qty ethanol total' ,loop(s, put lQeth(s)); put /;
put    'Qty eth from grain'       ,loop(s, put  lQethwh(s)); put /;
put   'Qty eth from beets'        ,loop(s, put lQethsb(s));  put /;
put  'Qty DDGS'                   ,loop(s, put  lQddgs(s));  put /;
put  'Qty pulp'                   , loop(s, put  lQpulp(s)); put /;
put   'total cost industry'       ,loop(s, put  ltcost(s)); put /;
put    'annual capital cost eth plant' , loop(s, put lcc_annual(s)) ;  put
/;

put "--------------------------------", put /;
put 'cost items in euro per ton ethanol',  put/;
put "--------------------------------", put /;
put  ,  'capital cost' , loop(s, put uccost(s)); put /;
put   'lab cost' , loop(s, put ulabcost(s)); put /;
put   'raw m cost' , loop(s, put ubiocost(s)); put /;
put   'inp cost' , loop(s, put uinpcost(s)); put /;
put  'other cost' ,loop(s, put umoicost(s)); put /;
put "--------------------------------", put /;
put  ,  'total cost' ,loop(s, put tucost(s)); put /;
put "--------------------------------", put /;
put  'salesunit' , preth, put /;
put  'sales by prod', loop(s, put ubyprod(s)); put /;
put "--------------------------------", put /;
put  'tot sales' , loop(s, put usales(s)); put /;
put  'profit industry' , loop(s, put lobj_1(s)); put /;
put  'total agril surplus', loop(s, put lobj_2(s)); put/;
put  'total prof industry', loop (s, put lobj_3(s)); put/;
put  'profit total' , loop(s, put lobj_essainlp(s)); put /;
put  'agric surplus' , loop(s, put lbasefarm_surplus(s)); put /;

put 'cost allocation on unitary basis', '%', put/;
put   'capital cost' , loop(s, put puccost(s)); put /;
put   'lab cost' , loop(s, put pulabcost(s)); put /;
put  'raw m cost' , loop(s, put pubiocost(s)); put /;
put 'inp cost' , loop(s, put puinpcost(s));  put /;
put  'other cost' , loop(s, put pumoicost(s)); put /;
put "--------------------------------", put /;
put "--------------------------------", put /;
put   'salesunit' , loop(s, put ppreth(s)); put /;
```

```
put   'sales by prod', loop(s, put pubyprod(s)); put /;
put "--------------------------------", put /;
put  'tot sales as percent of cost' , loop(s, put pusales(s)); put /;
put "--------------------------------", put /;
put "--------greenhouse gases agriculture-----------", put /;
put "--------------------------------", put /;
put  'diff agriculture', loop(s, put diffco2(s)); put /;
put  'diff transport', loop(s, put diffco2_tr(s)); put /;
put "--------industry-----------", put /;
put   'diff el', loop(s, put elect_in(s)); put /;
put  'diff steam', loop(s, put fuel_oil_stm(s)); put /;
put  'diff gasoline', loop(s, put CO2_gasoline(s)); put /;
put "--------total CO2 saved-----------", put /;
put  'diff overall', loop(s, put totCO2eth(s)); put /;
put "--------cost CO2 save-------------", put/;
put 'total CO2 saving cost', loop(s, put tottax_gasoline(s)); put/;
put 'CO2 save cost per ton', loop(s, put cost_CO2save_perton(s)); put/;

daggasau= sum((f,c),info(f,'weight')*x.l(f,c));
daggsurf(c)= sum(f,info(f,'weight')*x.l(f,c)/1000);
pricealf=alpha-beta*totalf.l;
file chec3/.\aggs_f_nlp.txt/; chec3.pc=6; put chec3; chec3.nd=5;
put " ", "sau",  loop(c, put c.tl); put / ;
put "obs2002",  reaggsau:0:0; loop(c, put aggosurf(c):0:3); put /;
put "opt 2002", aggasau:0:0; loop(c, put aggsurf(c):0:3); put /;
put "nlopt 2002", nlaggasau:0:0; loop(c, put nlaggsurf(c):0:3); put /;
put "decoupl_no_ethanol",  aggasau03:0:0; loop(c, put aggsurf03(c):0:3);
put /;
put "decoupl_with_ethanol",  daggasau:0:0; loop(c, put daggsurf(c):0:3);
put /;
put "info_alfalfa",  pricealf00, totalf.l, pricealf, alpha, beta:15:15;
```

INDUSTRY MODEL WITH BIOGAS FACILITY (configuration 2)

```
Parameters pw timi wheat/110/, pt timi teytlwn/32/
weth tranformation wheat to ethanol/0.299/, sbeth transformation sbt to
ethanol/0.067/
dd transformation wheat to ddgs/0.32/, plp transformation sbt to
poulpa/0.2/
elecw_eth  kWh per t EtOH wheat /503/, elecb_eth  kWh per t EtOH sbeet
/228.7/
preth timi eyhanol/820/, prdd timi ddgs/160/, prplp timi poulpas/14/, pel
price electr /0.05/
```

```
cchw cost chem ana t eth apo wheat/47.17/,  ccht cost chem ana t eth apo
sbt/19.53/
celw cost elec ana t eth apo wheat, celt cost elec ana t eth apo sbt/13.72/
cstw cost steam ana t eth apo wheat/180/, cstt cost steam ana t eth apo
sbt/159.12/

scalecoeff scale coefficient /0.61/,  base_invcost investment cost basis
/12410000/
basecap base capacity in tons /35000/
maxq maximum quantity /120000/;

celw=pel*elecw_eth; celt=pel*elecb_eth;

parameter biogas_basecap biogas base plant capacity (ton feedstock) (120
ton silage per day = 120*330 ton per year=) /39600/

*biogas_capacity: current biogas plant capacity (400 ton silage per day =
400*330 ton per year=) /132000/
biogas_basecap_cost biogas base capacity plant cost (euro)(including co-
generation unit) /4045602/
r_biogas biogas production rate (m3 per ton silage) /180/
r_elect_biogas electricity production rate from biogas (kWh per m3) /2.6/
;

*VARIABLES BIOGAS MODULE
biogas_capcost biogas plant capital cost (euro), bgcapcost_ann, bgas_cap
Qbiogas quantity of biogas production (m3 per year)
Qelect_biogas quantity of electricity production from biogas (kWh per year)
tot_elect_use total electricity used in the indusrial processing (kWh)
elect_excess electricity to be sold (kWh)
rev_elect_sale revenue from excess electricity sale (euro)
rev_pulp_sale revenue from excess pulp sale (euro)

equations
capitalcost tot cost calc, capannual annualized cost
land(f)   land constraint, irrig(f)  irrigated land
flexcotd(f) dry cotton, flexcot(f) inertia when cot, flexmzf(f) inertia
when ensiromeno mz
flexcer(f)   flexibility cereals, flextob(f) flexibility tobacco
flexpot(f) flex potato, decpot(f) potato only in non epileximi ektasi
demsgb(f)  sb contracts, demtom(f)  tom contracts, demcyn demand total
cynara
demcyn450,demcyn470, demsyn480, rotatalf(f) alfalfa rotation, water_alf(f)
demand constraint for alfalfa
vikoblig(f) obligatory env rotation, objectif  objective function base case
totmargnl non linear total margin, aggalf aggregate alfalfa production
```

```
posotita_sitari paragwgi potistikou sitariou, posotita_teytla paragwgi
teytlwn

quant_eth_w posotita ethanol apo wheat, quant_eth_sbt posotita ethanol apo
sbt
quant_eth total posotita ethanol, quant_dd posotita ddgs, quant_plp
posotita poulpas
ximika, electricity, atmos, labor1 ergasia manufacturing, syntirisi,
operations, labor2 ergasia administrative
insurance, general, external, grafika, diafora reyma kai nero, travel,
communication,
feedstock, totalcost
capacity1 capacity constraint 1, capacity2 capacity constraint 2,
production imerisia paragwgi
kerdos kerdos ergostasiou, stoxos enwsi dyo montelwn, stoxosCAP2000
previous CAP

bgas_capcost, bgas_capannual, bg_capac
bgas_quant
bgas_el
input_el
excess_el
sales_el
sales_pu
;

land(f).. sum(c, x(f,c))-x(f,'vik')=l=surface(f);
irrig(f).. sum(r, x(f,r))=l=1.1*rirrig(f);
flexcer(f)$surf(f,'cer')..  sum(cer, x(f,cer))=l=1000*surf(f,'cer');
flexcot(f)..  x(f,'cot')+x(f,'cotd')=l=surf(f,'cot')+surf(f,'cotd');
flexcotd(f)..  x(f,'cotd')=e=surf(f,'cotd');
flexmzf(f)..  x(f,'mzf')=l=3*surf(f,'mzf');
flextob(f).. x(f,'tob')=l=surf(f,'tob');
*$surf(f,'tob').. x(f,'tob')=l=1.2*surf(f,'tob');
decpot(f).. x(f,'pot')=l=surface(f)-decsurf(f);
flexpot(f).. x(f,'pot')=l=1.1*surf(f,'pot');
demsgb(f).. x(f,'sbt')=l=surf(f,'sbt');
demtom(f).. x(f,'tom')=l=1.1*surf(f,'tom');
demcyn.. sum(f, info(f,'weight')*yield(f, 'wir')*x(f, 'wir'))=g=0;
rotatalf(f).. x(f, 'alf')=l= rot_coeff*sum(rot, x(f,rot));
water_alf(f).. 200*x(f,'wir')+200*x(f,'cotd')+150*x(f, 'cots')+400*x(f,
'cot')+600*x(f, 'mze')+700*x(f, 'tob')+700*x(f, 'pot')
+800*x(f, 'sbt')+800*x(f, 'tom') +600*x(f, 'mzf')+700*x(f,
'alf')=l=1*wtcap(f);
vikoblig(f).. x(f,'vik')-oblig_percent*(dec_surf(f)-x(f,'alf'))=g=0;
```

```
objectif..  sum((f,c), info(f,'weight')*margha(f,c)*x(f,c))=e=totgm;
aggalf.. sum(f, info(f,'weight')*yield(f,'alf')*x(f,'alf'))=e=totalf;
totmargnl.. sum((f,cc), info(f,'weight')*margha(f,cc)*x(f,cc))
         +sum(f, info(f,'weight')*((alpha-(beta/2)*totalf)*yield(f,'alf')-
vcost(f,'alf'))*x(f,'alf'))=e=totgmnl;

posotita_sitari.. wirdem=l=(sum(f, info(f,'weight')*yield(f, 'wir')*x(f,
'wir')))/1000;
posotita_teytla.. sbtdem=l=(sum(f, info(f,'weight')*yield(f, 'sbt')*x(f,
'sbt')))/1000;
quant_eth_w.. Qeth_wir=e=weth*wirdem;
quant_eth_sbt.. Qeth_sbt=e=sbeth*sbtdem;
quant_eth.. Qeth_tot=e=weth*wirdem + sbeth*sbtdem;
quant_dd.. Qddgs=e=dd*wirdem;
quant_plp.. Qpoulpa=e=plp*sbtdem;
feedstock.. fst=e=pw*wirdem + pt*sbtdem;
ximika.. chem=e=cchw*Qeth_wir + ccht*Qeth_sbt;
electricity.. elec=e=celw*Qeth_wir + celt*Qeth_sbt;
atmos.. steam=e=cstw*Qeth_wir + cstt*Qeth_sbt;
labor1.. lab_man=e=612282.438+(2445.818*(Qeth_tot**0.49))-
(317272.68*(Qeth_tot**0.05));
syntirisi.. maint=e=990.172*(Qeth_tot**0.61)+(1.969*(Qeth_tot**0.84));
operations.. oper=e=99.017*(Qeth_tot**0.61)+(0.197*(Qeth_tot**0.84));
labor2.. lab_adm=e=-736287.216+(592242.336*(Qeth_tot**0.05));
insurance.. ins=e=495.086*(Qeth_tot**0.61)+(0.938*(Qeth_tot**0.84));
general.. gener=e=49.509*(Qeth_tot**0.61)+(0.099*(Qeth_tot**0.84));
external.. exter=e=-73628.722+(59224.234*(Qeth_tot**0.05));
grafika.. office=e=-18407.18+(14806.058*(Qeth_tot**0.05));
diafora.. elwat=e=-18407.18+(14806.058*(Qeth_tot**0.05));
travel.. trav=e=-73628.722+(59224.234*(Qeth_tot**0.05));
communication.. com=e=-36814.361+(29612.117*(Qeth_tot**0.05));
capitalcost..  totcapcost=e= 3.41*exp(scalecoeff*(log(Qeth_tot)-
log(basecap)));
capannual..   capcost_ann=e=totcapcost*base_invcost/((1-power((1+0.06),-
15))/0.06);

capacity1.. Qeth_tot =g= 10000;
capacity2.. Qeth_tot =l= maxq;
production.. Qeth_wir/230 =e= Qeth_sbt/100;
bg_capac.. bgas_cap=e=Qddgs*330/230;

bgas_capcost
.. biogas_capcost =e=exp(scalecoeff*(log(bgas_cap)-log(biogas_basecap)));
bgas_capannual.. bgcapcost_ann=e=biogas_capcost*biogas_basecap_cost/((1-
power((1+0.06),-15))/0.06);
bgas_quant.. Qbiogas =e= (Qddgs*330/230)*r_biogas;
```

```
bgas_el.. Qelect_biogas =e= Qbiogas*r_elect_biogas;
input_el.. tot_elect_use=e= (Qeth_wir*elecw_eth)+(Qeth_sbt*elecb_eth);
excess_el.. elect_excess =e= Qelect_biogas-tot_elect_use;
sales_el.. rev_elect_sale =e= elect_excess*pel;
sales_pu.. rev_pulp_sale =e= (Qpoulpa-Qddgs*100/230)*prplp;
totalcost.. totcost=e=capcost_ann + bgcapcost_ann
+chem+steam +lab_man
+maint+oper+lab_adm+ins -Qelect_biogas*pel
;
kerdos.. prof=e=preth*Qeth_tot+rev_pulp_sale
-totcost;
stoxosCAP2000.. synolo2000=e=prof+totgmnl;
stoxos.. synolo=e=prof+totgmnl;
bgas_cap.lo=0.00001;
file chec/.\param_lpgas.txt/; chec.pc=6; put chec; chec.nd=5;
put "totsub", 'SFP',  loop(c, put c.tl); put / ;
put totsubs('1'), cheque('1'), loop(c, put yield('1', c)); put / ;
put "subkg ", " ",  loop(c, put subkg('1', c)); put / ;
put "subs ", " ",  loop(c, put subs('1', c)); put / ;
put "price ", " ",  loop(c, put prix('1', c)); put / ;
put "vcost ", " ",  loop(c, put vcost('1', c)); put / ;
put "gmargin ", " ",  loop(c, put margha('1', c)); put / ;

options limrow=4,limcol=4; model essai/land, irrig, flexcotd, flexcot,
flexmzf, flextob
flexpot, demsgb, demtom, rotatalf, water_alf, objectif
/;
essai.scaleopt=1 ; option lp=cplex; solve essai using lp maximizing totgm;

parameter optq_co2eq optimal level base year; optq_co2eq=sum((f,c),
co2eq(c)*info(f,'weight')*x.l(f,c)/1000);

parameter reaggsau really cultivated land, aggsau obs, aggasau actual total
sau cultivated, nlaggasau  nlp
aggosurf(c) agg obs surf per crop, aggsurf(c) agg crop cultivated,
nlaggsurf(c) agg crop cultivated nlp,
surfcult(f) surface really cultivated in 2002;
surfcult(f)=sum(c, surf(f,c));

*fix problem of fake unused land because of declared SAU exceeding
cultivated surface in 2002
aggsau=sum(f, info(f,'weight')*surf(f, 'sau')); reaggsau=sum(f,
info(f,'weight')*surfcult(f));
aggasau=sum((f,c), info(f,'weight')*x.l(f,c));
aggosurf(c)= sum(f, info(f,'weight')*surf(f,c)/1000);
aggsurf(c)= sum(f, info(f,'weight')*x.l(f,c)/1000);
```

```
options limrow=4,limcol=4; model essainl/land, irrig, flexcotd, flexcot,
flexmzf, flextob
flexpot, demsgb, demtom, rotatalf, water_alf, aggalf, totmargnl/;
essainl.scaleopt = 1 ; option lp=cplex; solve essainl using nlp maximizing
totgmnl;

nlaggsurf(c)= sum(f, info(f,'weight')*x.l(f,c)/1000);
nlaggasau=sum((f,c), info(f,'weight')*x.l(f,c));
parameter pricealf00; pricealf00=alpha-beta*totalf.l;

*CALCULATIONS AVERAGE VALUES
parameters
cy(fe,c) count, toty(c) number of f per c, avyd(c) mean global, avy(re,c)
regional
p(f,c) only positive prices, cp(f,c) count, totp(c) number of f per c,
avp(c) mean
k(f,c) only positive subkg, ck(f,c) count, totk(c) number of f per c,
avk(c) mean
s(f,c) only positive subs, cs(f,c) count, tots(c) number of f per c, avs(c)
mean
v(f,c) only positive vcost, cv(f,c) count, totv(c) number of f per c,
avv(c) mean
;

cy(f470,c)$yield(f470,c)=info(f470, 'weight'); toty(c)=sum(f470,
cy(f470,c));
avy("470",c)$toty(c)=sum(f470, info(f470, 'weight')*yield(f470,c))/toty(c);
cy(f480,c)$yield(f480,c)=info(f480, 'weight'); toty(c)=sum(f480,
cy(f480,c));
avy("480",c)$toty(c)=sum(f480, info(f480, 'weight')*yield(f480,c))/toty(c);
avyd(c)=sum(re, avy(re, c))/4; avyd('sfw')=290;
p(f,c)$prix(f,c)=prix(f,c); cp(f,c)$p(f,c)=1; totp(c)=sum(f, cp(f,c));
avp(c)$totp(c)=sum(f, prix(f,c))/totp(c); avp('cyn')=0.0;
k(f,c)$subkg(f,c)=subkg(f,c); ck(f,c)$k(f,c)=1; totk(c)=sum(f, ck(f,c));
avk(c)$totk(c)=sum(f, subkg(f,c))/totk(c);
s(f,c)$subs(f,c)=subs(f,c); cs(f,c)$s(f,c)=1; tots(c)=sum(f, cs(f,c));
avs(c)$tots(c)=sum(f, subs(f,c))/tots(c);
v(f,c)$vcost(f,c)=vcost(f,c); cv(f,c)$v(f,c)=1; totv(c)=sum(f, cv(f,c));
avv(c)$totv(c)=sum(f, vcost(f,c))/totv(c);

parameter price(f, c) all prices, yiel(*, c) obs yield plus projected for
those no, varc(f,c) same purpose;
yiel(f470,c)$(yield(f470,c) eq 0)=avy("470",c);
yiel(f480,c)$(yield(f480,c) eq 0)=avy("480",c);
```

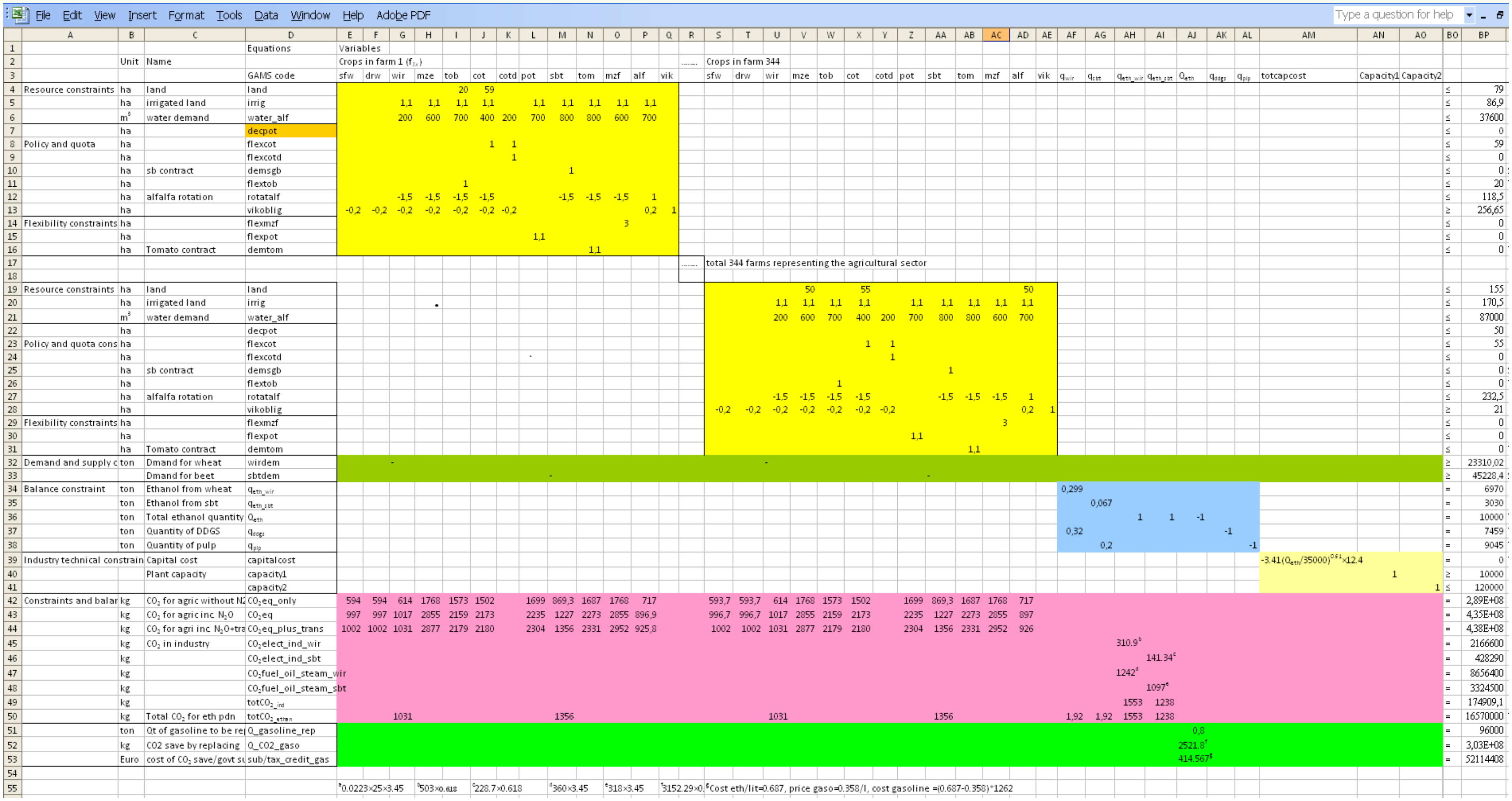
```
yiel(f480,'sfw')=avy("470",'sfw');yield(f,c)=yield(f,c)+yiel(f,c);
price(f,c)$(prix(f,c) eq 0)=avp(c); price(f,c)=prix(f,c)+price(f,c);
price(f, 'alf')=.15;
varc(f,c)$(vcost(f,c) eq 0)=avv(c); vcost(f,c)=varc(f,c)+vcost(f,c);
subs(f,c)=0; subs(f, 'drw')=10; subs(f, 'mze')=10;
subkg(f,c)=0; subkg(f,'tom')=0.035; subs(f,'cotd')=55;
subs(f,'cot')=subs(f,'cotd'); subs(f,'cots')=subs(f,'cotd');
yield(f, 'wir')=1.5*yield(f,'cot');
subs(f, 'wir')=4.5;
price(f, 'sbt')=.0; price(f, 'wir')=.0;
subs(f,'sbt')=32; subs(f, 'sbt')=subs(f, 'sbt')+4.5;
margha(f,c)
=(price(f,c)+subkg(f,c))*yield(f,c)+subs(f,c)-vcost(f,c);

Qeth_tot.lo=1;
Qeth_sbt.lo=0.0001;

*file chec9/.\param_lpost.txt/; chec9.pc=6; put chec9; chec9.nd=5;
put "totsub", 'SFP',  loop(c, put c.tl); put / ;
put totsubs('1'), cheque('1'), loop(c, put yield('1', c)); put / ;
put "subkg ", " ",  loop(c, put subkg('1', c)); put / ;
put "subs ", " ",  loop(c, put subs('1', c)); put / ;
put "price ", " ",  loop(c, put prix('1', c)); put / ;
put "vcost ", " ",  loop(c, put vcost('1', c)); put / ;
put "gmargin ", " ",  loop(c, put margha('1', c)); put / ;

options limrow=4,limcol=4; model essai03/land, irrig, flexcotd, flexcot,
flexmzf, flextob
flexpot, demsgb, demtom, rotatalf, water_alf, vikoblig, objectif
/;
option lp=cplex; solve essai03 using lp maximizing totgm;

parameters aggasau03,  aggsurf03 lp CAP2003, obj_essai03;
aggasau03=sum((f,c), info(f,'weight')*x.l(f,c));
aggsurf03(c)= sum(f, info(f,'weight')*x.l(f,c)/1000);
obj_essai03=totgmnl.l;
parameter newCAP_nlpq_co2eq optimal level nlp new CAP without industry;
parameter newCAP_nlp_trans_co2eq optimal level nlp new CAP without
industry;
newCAP_nlpq_co2eq=sum((f,c), co2eq(c)*info(f,'weight')*x.l(f,c)/1000);
newCAP_nlp_trans_co2eq=sum((f,c), (co2eq_plus_trans(c)-
co2eq(c))*info(f,'weight')*x.l(f,c)/1000);

model essainlp /
land, irrig, flexmzf, decpot, flexpot, demsgb, demcyn, demtom, rotatalf
```

```
water_alf, objectif, aggalf, vikoblig, totmargnl, posotita_sitari,
posotita_teytla
capitalcost, capannual
quant_eth_w, quant_eth_sbt, quant_eth, quant_dd, quant_plp
ximika, electricity, atmos, labor1     ,
syntirisi, operations, labor2
insurance, general, external, grafika, diafora, travel, communication
totalcost, capacity1, capacity2, production, kerdos
bgas_capcost, bgas_capannual, bg_capac, bgas_quant, bgas_el, input_el,
excess_el, sales_el, sales_pu, stoxos
/;
options limrow=3,limcol=3; essainlp.scaleopt = 1 ; option nlp=conopt;
solve essainlp using nlp maximizing synolo;
parameter basefarm_surplus, obj_essainlp, obj_1, obj_2, obj_3  ;

basefarm_surplus=(totgmnl.l-obj_essai03)/Qeth_tot.l;
obj_1=prof.l/Qeth_tot.l; obj_essainlp=synolo.l; obj_2=totgmnl.l; obj_3=
prof.l;

parameter daggasau, daggasau8 actual total sau cultivated after decoupling
daggsurf(c), daggsurf8(c) agg crop cultivated after dec;
daggasau= sum((f,c),info(f,'weight')*x.l(f,c));
daggsurf(c)= sum(f,info(f,'weight')*x.l(f,c)/1000);
parameter pricealf; pricealf=alpha-beta*totalf.l;
parameters matinp, labour, m_o_ins, uccost capital cost per ton ethanol,
ubiocost, uinpcost, ulabcost, uelecost, umoicost, u_el
u_pulp, tucost, puccost capital cost percent of total cost, pubiocost,
puinpcost, pulabcost, pumoicost, pu_el, pu_pulp
puelecost, usales, pusales, ubyprod, pubyprod, ppreth ;

matinp=chem.l+steam.l; labour=lab_man.l+lab_adm.l;
m_o_ins=maint.l+oper.l+ins.l;
uccost=(capcost_ann.l+bgcapcost_ann.l)/Qeth_tot.l;
ubiocost=(posotita_sitari.m*wirdem.l+posotita_teytla.m*sbtdem.l)/Qeth_tot.l
;
uinpcost=matinp/Qeth_tot.l; ulabcost=labour/Qeth_tot.l;
umoicost=m_o_ins/Qeth_tot.l;
uelecost=-(Qelect_biogas.l*pel)/Qeth_tot.l;
tucost=uccost+ubiocost+uinpcost+ulabcost+umoicost+uelecost;
puelecost=uelecost/tucost; puccost=uccost/tucost;
pubiocost=ubiocost/tucost;
puinpcost=uinpcost/tucost; pulabcost=ulabcost/tucost;
pumoicost=umoicost/tucost;
usales=(preth*Qeth_tot.l+rev_pulp_sale.l+rev_elect_sale.l)/Qeth_tot.l;
pusales=usales/tucost;
```

```
ubyprod=(rev_pulp_sale.l+rev_elect_sale.l)/Qeth_tot.l;
pubyprod=ubyprod/tucost; ppreth=preth/tucost;

u_el=(rev_elect_sale.l)/Qeth_tot.l; u_pulp=(rev_pulp_sale.l)/Qeth_tot.l;
pu_el=u_el/tucost;  pu_pulp=u_pulp/tucost;
usales=(preth*Qeth_tot.l+
rev_pulp_sale.l)/Qeth_tot.l; pusales=usales/tucost;

put  uccost,  'capital cost' , puccost, put /;
put  ulabcost,  'lab cost' , pulabcost, put /;
put  ubiocost,  'raw m cost' , pubiocost, put /;
put  uinpcost,  'chem & steam inp cost' , puinpcost, put /;
put  uelecost,  'electr inp cost' , puelecost, put /;
put  umoicost,  'other cost' , pumoicost, put /;
put "-------------------------------", put /;
put  tucost,  'total cost' , 1, put /;
put "-------------------------------", put /;
put  preth, 'sales eth' , ppreth, put /;
put  u_el, 'sales excess el',  put pu_el, put /;
put  u_pulp, 'sales pulp', pu_pulp, put /;
put "-------------------------------", put /;
put  usales, 'tot sales incl only eh+pulp' , pusales, put /;
put  " ", 'profit industry' , obj_1, put /;
put  " ", 'profit total' , obj_essainlp, put /;
put  " ", 'agric surplus' , basefarm_surplus, put /;
put  " ", 'total agril surplus', obj_2, put /;
put  " ", 'total profit industry', obj_3, put/;

put ' ', 'results ethanol plant at the optimum' ,  put /;
put wirdem.l,  ' Qty wheat', posotita_sitari.m ,  'dual price wheat', put
/;
put  sbtdem.l,  'Qty sbt' , posotita_teytla.m , 'dual price sugar beet',
put /;
put  Qeth_tot.l,  'Qty ethanol total' , put /;
put  Qeth_wir.l,  'Qty eth from grain'       , put /;
put  Qeth_sbt.l,  'Qty eth from beets'           , put /;
put  Qddgs.l,  'Qty DDGS'                            , put /;
put  Qpoulpa.l,  'Qty pulp'                            , put /;
put  totcost.l,  'total cost industry'                              , put
/;
put prof.l,  'tot profit industry'
, put /;
put  synolo.l,  'total surplus agriculture plus industry'
,put  /;
put  totcapcost.l,  'total capital cost ethanol'
,put  /;
```

```
put  biogas_capcost.l,  'total capital cost biogas'
,put  /;
put capcost_ann.l,  'annual capital cost eth plant' , put /;
put bgcapcost_ann.l,  'annual capital cost biogas plant' , put /;

parameter globnlpq_co2eq optimal level nlp new CAP plus industry,
globnlp_trans_co2eq transport;
globnlpq_co2eq=sum((f,c), co2eq(c)*info(f,'weight')*x.l(f,c)/1000);
globnlp_trans_co2eq = sum((f,c), (co2eq_plus_trans(c)-
co2eq(c))*info(f,'weight')*x.l(f,c)/1000);
parameter diffco2 difference new CAP with and without ethanol, diff_ton;
diffco2= globnlpq_co2eq-  newCAP_nlpq_co2eq;
diff_ton=  diffco2/Qeth_tot.l;
parameter diffco2_tr difference new CAP with and without ethanol incl
transport cost, diff_ton_tr;
diffco2_tr= globnlp_trans_co2eq -  newCAP_nlp_trans_co2eq;
diff_ton_tr=  diffco2_tr/Qeth_tot.l;
```

APPENDIX IX: GAMS code in excel sheet



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	BO	BP
1				Equations	Variables																																						
2		Unit	Name		Crops in farm 1 (f_{1x})													…….	Crops in farm 344																								
3				GAMS code	sfw	drw	wir	mze	tob	cot	cotd	pot	sbt	tom	mzf	alf	vik		sfw	drw	wir	mze	tob	cot	cotd	pot	sbt	tom	mzf	alf	vik	q_{wir}	q_{sbt}	q_{eth_wir}	q_{eth_sbt}	Q_{eth}	q_{ddgs}	q_{plp}	totcapcost	Capacity1	Capacity2		
4	Resource constraints	ha	land	land					20	59																																≤	79
5		ha	irrigated land	irrig			1,1	1,1	1,1	1,1		1,1	1,1	1,1	1,1	1,1																										≤	86,9
6		m^3	water demand	water_alf			200	600	700	400	200	700	800	800	600	700																										≤	37600
7		ha		decpot																																						≤	0
8	Policy and quota	ha		flexcot						1	1																															≤	59
9		ha		flexcotd							1																															≤	0
10		ha	sb contract	demsgb									1																													≤	0
11		ha		flextob					1																																	≤	20
12		ha	alfalfa rotation	rotatalf			-1,5	-1,5	-1,5	-1,5			-1,5	-1,5	-1,5	1																										≤	118,5
13		ha		vikoblig	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2					0,2	1																									≥	256,65
14	Flexibility constraints	ha		flexmzf											3																											≤	0
15		ha		flexpot								1,1																														≤	0
16		ha	Tomato contract	demtom										1,1																												≤	0
17																		…….	total 344 farms representing the agricultural sector																								
18																																											
19	Resource constraints	ha	land	land																		50		55						50												≤	155
20		ha	irrigated land	irrig																	1,1	1,1	1,1	1,1		1,1	1,1	1,1	1,1	1,1												≤	170,5
21		m^3	water demand	water_alf																	200	600	700	400	200	700	800	800	600	700												≤	87000
22		ha		decpot																																						≤	50
23	Policy and quota cons	ha		flexcot																				1	1																	≤	55
24		ha		flexcotd																					1																	≤	0
25		ha	sb contract	demsgb																							1															≤	0
26		ha		flextob																			1																			≤	0
27		ha	alfalfa rotation	rotatalf																	-1,5	-1,5	-1,5	-1,5			-1,5	-1,5	-1,5	1												≤	232,5
28		ha		vikoblig															-0,2	-0,2	-0,2	-0,2	-0,2	-0,2	-0,2					0,2	1											≥	21
29	Flexibility constraints	ha		flexmzf																									3													≤	0
30		ha		flexpot																						1,1																≤	0
31		ha	Tomato contract	demtom																								1,1														≤	0
32	Demand and supply c	ton	Dmand for wheat	wirdem			-														-																					≥	23310,02
33			Dmand for beet	sbtdem									-														-															≥	45228,4
34	Balance constraint	ton	Ethanol from wheat	q_{eth_wir}																												0,299										=	6970
35		ton	Ethanol from sbt	q_{eth_sbt}																													0,067									=	3030
36		ton	Total ethanol quantity	Q_{eth}																														1	1	-1						=	10000
37		ton	Quantity of DDGS	q_{ddgs}																												0,32					-1					=	7459
38		ton	Quantity of pulp	q_{plp}																													0,2					-1				=	9045
39	Industry technical constrain		Capital cost	capitalcost																																			$-3.41(Q_{eth}/35000)^{0.61}\times12.4$			=	0
40			Plant capacity	capacity1																																				1		≥	10000
41				capacity2																																					1	≤	120000
42	Constraints and balar	kg	CO$_2$ for agric without N2	CO$_2$eq_only	594	594	614	1768	1573	1502		1699	869,3	1687	1768	717			593,7	593,7	614	1768	1573	1502		1699	869,3	1687	1768	717												=	2,89E+08
43		kg	CO$_2$ for agric inc N$_2$O	CO$_2$eq	997	997	1017	2855	2159	2173		2235	1227	2273	2855	896,9			996,7	996,7	1017	2855	2159	2173		2235	1227	2273	2855	897												=	4,35E+08
44		kg	CO$_2$ for agri inc N$_2$O+tra	CO$_2$eq_plus_trans	1002	1002	1031	2877	2179	2180		2304	1356	2331	2952	925,8			1002	1002	1031	2877	2179	2180		2304	1356	2331	2952	926												=	4,38E+08
45		kg	CO$_2$ in industry	CO$_2$elect_ind_wir																														310.9^b								=	2166600
46		kg		CO$_2$elect_ind_sbt																															141.34^c							=	428290
47		kg		CO$_2$fuel_oil_steam_wir																														1242^d								=	8656400
48		kg		CO$_2$fuel_oil_steam_sbt																															1097^e							=	3324500
49		kg		totCO$_{2\_ind}$																														1553	1238							=	174909,1
50		kg	Total CO$_2$ for eth pdn	totCO$_{2\_ethan}$			1031						1356								1031						1356					1,92	1,92	1553	1238							=	16570000
51		ton	Qt of gasoline to be re	Q_gasoline_rep																																0,8						=	96000
52		kg	CO2 save by replacing	Q_CO2_gaso																																2521.8^f						=	3,03E+08
53		Euro	cost of CO$_2$ save/govt su	sub/tax_credit_gas																																414.567^g						=	52114408
54																																											
55					^{a}0.0223×25×3.45			^{b}503×0.618		^{c}228.7×0.618			^{d}360×3.45		^{e}318×3.45		^{f}3152.29×0.		^{g}Cost eth/lit=0.687, price gaso=0.358/l, cost gasoline =(0.687-0.358)*1262																								

APPENDIX X: Cost and returns of ethanol production system for different capacities and different scenarios (є/t)

Item	Without Biogas Plant							With Biogas Plant						
Plant capacity(kt)	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Scenario under CAP 2003 [area subsidy on cotton @ 55 (є/h)]														
Capital cost	100.9	95.0	90.2	86.1	82.7	79.6	77.0	110.2	103.8	98.5	94.1	90.3	87.0	84.1
Labour cost	14.8	13.4	12.2	11.3	10.5	9.9	9.4	14.8	13.4	12.2	11.3	10.5	9.9	9.4
Raw material cost	477.0	488.6	499.6	504.5	507.2	511.7	526.4	477.0	488.6	499.6	504.5	507.2	511.7	526.4
Input cost (elect, chemic, steam)	237.7	237.7	237.7	237.7	237.7	237.7	237.7	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Other cost	22.2	20.9	19.9	19.0	18.3	17.6	17.0	22.2	20.9	19.9	19.0	18.3	17.6	17.0
Total cost	**852.6**	**855.6**	**859.5**	**858.6**	**856.3**	**856.6**	**867.4**	**836.8**	**839.1**	**842.7**	**841.4**	**838.8**	**838.7**	**849.3**
Sales by product*	132.0	132.0	132.0	132.0	132.0	132.0	132.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Cost after by product sales	**720.6**	**723.5**	**727.5**	**726.6**	**724.3**	**724.5**	**735.4**	**824.6**	**827.0**	**830.5**	**829.2**	**826.6**	**826.6**	**837.2**
Scenario under CAP 2003 revised in 2008 [coupled area subsidy on cotton @ 80 (є/h)]														
Capital cost	100.9	95.0	90.2	86.1	82.7	79.6	77.0	110.2	103.8	98.5	94.1	90.3	87.0	84.1
Labour cost	14.8	13.4	12.2	11.3	10.5	9.9	9.4	14.8	13.4	12.2	11.3	10.5	9.9	9.4
Raw material cost	541.5	556.4	577.2	588.1	600.0	606.2	615.8	541.5	556.4	577.2	588.1	600.0	606.2	615.8
Input cost (elect, chemic, steam)	237.7	237.7	237.7	237.7	237.7	237.7	237.7	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Other cost	22.2	20.9	19.9	19.0	18.3	17.6	17.0	22.2	20.9	19.9	19.0	18.3	17.6	17.0
Total cost	**917.1**	**923.3**	**937.1**	**942.2**	**949.1**	**951.0**	**956.8**	**901.2**	**906.9**	**920.3**	**925.0**	**931.6**	**933.2**	**938.7**
Sales by product*	132.0	132.0	132.0	132.0	132.0	132.0	132.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Cost after by product sales	**785.1**	**791.3**	**805.1**	**810.2**	**817.1**	**819.0**	**824.8**	**889.0**	**894.7**	**908.1**	**912.8**	**919.4**	**921.0**	**926.6**

* DDGS and pulp for without biogas plant and excess electricity and excess pulp for with biogas plan.

APPENDIX XI: Published work

1. Haque, M. I, Rozakis, S., Ganko, E., Kallivroussis, L., 2009. Bio-energy production in the sugar industry: an integrated modeling approach. Paper presented at the 113th EAAE Seminar "A resilient European food industry and food chain in a challenging world". Chania, Crete, Greece. Published online as working paper and under review to publish to the Biomass and Bioenergy Journal. (http://econpapers.repec.org/paper/agseaa113/58026.htm).

2. Haque, M. I., Rozakis, S. and Natsis, A. 2011. An integrated model to evaluate bio-energy production in the sugar industry and cost of CO_2 saving. Paper presented in the poster presentation session at the 19th European Biomass Conference and Exhibition (EU BC&E) , June 6-10, 2011, ICC Berlin, Germany.

3. Kremmydas, D., Haque, M. I., Rozakis, S., 2011. Enhancing Web-Spatial DSS interactivity with parallel computing: The case of bio-energy economic assessment in Greece. Paper accepted to be presented at the 10th Balkan Conference on Operational Research, September 22-25, Thessaloniki, Greece.

4. Haque M. I., S. Rozakis, A. Natsis, M. Borzecka-Walker, and K. Mizak. Policy dependent CO_2 emissions of bio-ethanol in Greece: a consequential assessment using non-linear programming activity models. Submitted to the International Journal of Life Cycle Assessment.

Bio-energy production in the sugar industry: an integrated modeling approach

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Paper prepared for presentation at the 113th EAAE Seminar "A resilient European food industry and food chain in a challenging world", Chania, Crete, Greece, date as in: September 3 - 6, 2009

Bio-energy production in the sugar industry: an integrated modeling approach

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Abstract: *Recent reforms in the Common Agricultural Policy and the sugar regime caused serious concerns for the future of the European sugar industry. At the same time, the European Commission considers transportation bio-fuels as a key factor for reducing reliance on imported fuels, emission levels of greenhouse gases and to meet rural development goals. Matching the sugar sector with bio-ethanol production may create opportunities for sustainable management of the existing sugar industry infrastructure and also serve bio-fuel policy targets.*

A partial equilibrium economic model is used in order to evaluate the shift from sugar to bio-ethanol production in Thessaly, Greece. In the agricultural feedstock supply and industrial processing sub-models are articulated indicating optimal crop mix for farmers and the best technology configurations for industry. The joint ethanol-biogas option appears to be preferable using sugar beet and wheat, whereas capacity selected amounts at 120 kt of ethanol.

Keywords. Sugar beet, grain, ethanol, mathematical programming, Greece

1. Introduction

Bioenergy refers to the energy produced from biological sources or biomass. Biomass may either be burned directly or converted into liquid or gaseous fuel. Bio-energy production in the sugar industry includes mainly production of bioethanol for automotive fuel purposes. Ethanol is the most common biofuel worldwide, accounting for more than 85% of the total biofuel uses[1] .Ethanol is typically blended with gasoline in order to expand supply, increase the octane rating of gasoline, and make it a less polluting, cleaner burning fuel. Internal combustion engines optimized for operation on alcohol fuels are 20 per cent more energy-efficient than when operated on gasoline[2], and an engine designed specifically to run on ethanol can be 30 per cent more efficient[3].

Recent changes in European policies concerning the sugar and the bio-fuel sector, that complete 2003 Common Agricultural Policy (CAP) decoupling reform, create a favourable environment for ethanol production by ex-sugar factories in Europe. This paper undertakes an economic evaluation of alternative ethanol production schemes in Central Greece (Thessaly) using sugar beet and wheat. Ethanol production is simulated in a mathematical programming model that is coupled to an arable sector agricultural supply model. Agro-industry surplus is maximised subject to linear and non-linear constraints in order to determine optimal industry configuration and size as well as energy crop quantities and opportunity costs.

The paper is organised as follows: section 2 overviews the institutional environment and relevant policies. In section 3 technical options and information on sugar-to-ethanol transformation are detailed. Modeling methodology and the case study are presented in sections 4 and 5 respectively. Optimisation results and discussion are given in section 6, and section 7 comprises some concluding remarks and ideas for further research.

2. Institutional framework: CAP Reform and the European Sugar Industry

The creation of a common agricultural policy was proposed by the European Commission. It followed the signing of the Treaty of Rome in 1957, which established the Common Market. The Common Agricultural Policy (CAP) was agreed to at the Stresa conference in July 1958. The CAP established a common pricing system for all farmers in the member countries, and fixed agricultural prices above world market levels to protect farmers in member countries who generally had higher production costs than other world market producers.

The main purpose of the Common Market Organization (CMO) in the sugar sector when it was created in 1968, was to guarantee sugar producers a fair income to provide self-sufficiency in sugar throughout the Community. High prices paid by the consumers encouraged sugar production in Community and import levies were used to deter imports from non-EU countries. The essential features of the sugar regime were a support price (a guaranteed minimum prices to sugar growers and producers to support the market); production quotas to limit production and distribute it across the European community; tariffs and quotas on sugar imports from non-EU countries; and, subsidies to export the surplus of sugar production out of the European Union[4].

Strong support and protection given to the EU sugar sector had many different results. First, the EU became a net exporter of sugar as the supply expanded well beyond the demand. By driving a wedge between world market prices and prices prevailing inside the EU, the Sugar CMO originates a transfer of wealth from consumers to producers and refiners. Also, since the excess production was exported with refunds, sugar producers received the same revenues as they would selling the sugar inside the EU market. Such subsidized exports depressed world market prices, making other producers worse off. Since its creation in 1968, the CMO for sugar has changed only marginally. The first change was in 1975 following the United Kingdom’s accession, when the CMO incorporated that country’s previous commitments to certain African, Caribbean, and Pacific (ACP) countries to import raw cane sugar for refining and subsequent sale on the UK market. The second big modification came in 1995 following the Uruguay Round, with a restriction on export refunds. The CMO was adjusted by making provision to reduce quotas in the event that the limit on refunds meant that the available surplus on the Community market could no longer be exported with refund. Since then, in practice, if imports increased the market equilibrium was re-established by reducing Community quotas (reduction mechanism)[5,6].

However, CMOs success in making sugar one of the most profitable crops in many EU countries has succeeded in delaying reform proposals until recently. The principal causes for reforming the sugar program at 2005 are threefold: (1) the CAP reforms of 2003/04 moving from commodity support to direct area payments (that left sugar as the only major commodity unreformed) ; (2) the “Everything But Arms” (EBA)[1] agreement, allowing the 48 least developed countries duty-free access to the EU sugar market by 2009; and (3) a World Trade Organization (WTO) Panel ruling that found the EU sugar regime in violation of WTO export commitments. Additionally, the EU offer to eliminate export subsidies in the Doha Round of WTO negotiations played a role in shaping the reform proposal[7]. These events led to the European Commission’s proposal to drastically reform sugar in 2005.

The reform proposals were designed to continue with its recent reforms of the CAP and to meet its international obligations. The stated aims of the reform are (1) to encourage reductions in domestic sugar output, particularly in regions with high production costs or lower sugar beet yields; (2) to bring export subsidies in line with WTO commitments; (3) to dampen incentives for EU sugar imports from the EBA countries; and (4) to reduce the price gap between sugar and competing sweeteners to forestall the substitution of sugar. The basic features of the proposal are[8]:

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[1] Traditionally, it has been admitted that the group of least developed countries (LDCs) should receive more favourable treatment than other developing countries. Gradually, market access for products from these countries has been fully liberalised. In February 2001, the Council adopted Regulation (EC) 416/2001, the so-called "EBA Regulation" ("Everything But Arms"), granting duty-free access to imports of all products from LDC's, except arms and munitions, without any quantitative restrictions (with the exception of bananas, sugar and rice for a limited period).

- ❑ Sugar price is reduced by 36 percent over a 4-year phase-in period beginning from 2006/07 (to ensure sustainable market balance, -20 percent in year one, -25 percent in year two, -30 percent in year three and -36 percent in year four).
- ❑ Minimum sugar beet price is reduced by 39.5 percent to €26.3/metric ton over the phase-in period.
- ❑ Sugar production quotas are not reduced except through a voluntary 4-year restructuring program where quota can be sold and retired. Payments for quota are €730/mt for 2006/07 and 2007/08; €625/mt for 2008/09 and €520/mt for 2009/10.
- ❑ Restructuring is financed by quota levies on producers and processors who do not sell quota. Total value of the restructuring fund is projected at €5.704 billion.
- ❑ Compensation is available to farmers at an average of 64.2 percent of the price cut. The aid is included in the Single Farm Payment and is linked to payments for compliance with environmental and land management standards.
- ❑ Establishment of a prohibitive super levy to be applied to over-quota production.
- ❑ Non-food sugar (sugar for the chemical and pharmaceutical industries and for the production of bioethanol) will be excluded from production quotas.

The new Common Market Organization in the sugar sector, which began in effect from July 2006, includes progressive reduction of prices of sugar and sugar beets as well as the reduction of quotas of sugar for each of EU country. These developments affected beet production dramatically, due to the sugar beet cultivation becoming economically disadvantageous and the sugar industries decreasing their production. According to estimates by the European Commission, total EU sugar production should fall to 12.2 million tons per year, which is equal to a decline of 43 per cent from the 2005 base year[8] . To achieve the target, based on estimates of the combined profitability of the industry (growers & manufacturers) the commission classified EU-25 sugar producing Member States into three groups, depending on their level of costs.

- ❑ Member States where sugar production is likely to be drastically reduced or even phased out: Greece, Ireland, Italy, Portugal;
- ❑ Member States in the border zone: Czech Republic, Spain, Denmark, Latvia, Lithuania, Hungary, Slovakia, Slovenia and Finland. In these MS, production is likely to be maintained but at a significantly lower level;
- ❑ Member States where the decrease in sugar production will be limited. It is even likely that overall production would not decrease in some MS: Austria, Belgium, France, Germany, the Netherlands, Poland, Sweden and the UK.

The main achievements of the first three years (2006 until 2009/10 (provisional status on January 2009)) of the restructuring is 5.77 million tones of quota renounced and out of 184 sugar factories, 79 have closed[9, 10]. Though the price for the consumer remained the same, the price for the producer reduced. According to EBA initiative there has been a reduction of import duties on sugar by 20% on 1 July 2006, by 50% on 1 July 2007, and by 80% on 1 July 2008 until their entire elimination on 1 July 2009[7]. In this situation the reference price has been dramatically reduced from €631.9 to €541.5 per ton from 1st of October 2008. Considering quota and duty free entrance of LDCs country to the EU market, the reference price from 1st of October 2009 will be €404.4 per ton[11].

3. Transformation from Sugar to Ethanol Production

Bio-ethanol can be produced from any feedstock that contains significant amounts of sugars or glucose polymers such as starch and cellulose that can be converted into glucose via hydrolysis. Sugar obtained from feedstock such as sugar beets, sugar cane and ‘molasses’, a by-product from sugar production, can be fermented directly. Starch from feed-stocks such as corn, potatoes, wheat, rye, barley and sorghum is a glucose polymer that must be hydrolyzed using enzymes to glucose monomers prior to fermentation.

With changes in the EU sugar regime, and with WTO ruling, the Common Market Organization in the EU has excluded sugar and sugar beet for non-food use (sugar for the chemical and pharmaceutical industries and for energy purposes) from production quota restriction. Simultaneously, the European Commission substantially promotes bio-fuels for environmental reasons and in order to ensure a minimal level of energy independence of EU. The States reduced their requirement for tax (the special tax in the petroleum products is basic source of income in all developed countries) when the fuel is from non-fossil origin, which renders competitive bio-fuels that usually cost twice as conventional fossil fuels. The EU sugar regime set compensation, by the EU regulation (EC) 320/ 2006 both for growers and industries. Compensation for producers and beet growers was set at amounts of €145.5M for restructuring, €43.6M for diversification and €123M for growers. In particular, it outlines that 100% of the restructuring compensation will be made available if full dismantling of production facilities occurs, while 75% of compensation will be made available if the option of partial dismantling of facilities is taken (i.e., a reduction of €36.4M if some facilities are retained)[12]. So, both the partial and complete transformation of production facility for bio-ethanol in the sugar industry is supported by the regulation and according to the requirement and commodity price, i.e. price ratio of sugar to ethanol, one can choose an optimal ratio between sugar and ethanol production.

Under the new CAP, the Greek sugar quota has reduced by 50.2 percent and the Hellenic Sugar Industry (HIS) has benefited by the amount of €118 million from the EU. In order for the HSI to accept the reduction of the quota by 50.2 percent, the EU has offered financial support to the Greek Industry to be spent for restructuring and investment. For Greece, the initial amount decided and agreed was at €118 million, of which to date 87 million have already been paid to HSI and the remaining 31 million will not be paid unless H.S.Co. finally implements its bio-ethanol program[13] .
The option of the H.S.Co. to convert altogether two sugar plants to ethanol production was announced in 2006, however despite consecutive calls to investors the process is still open and the sugar factories ceased operation without starting ethanol production. In this exercise we will evaluate the conversion of the sugar factory in Thessaly to ethanol, following two different configurations:

The first configuration comprises the raw biomass processing units that outflow their product after first transformation phase towards the Bio-ethanol production unit. The sugar-beet processing unit also produces pulp top shoots. Besides ethanol stillage from grain and sugar-beet being produced, the former is used to produce DDGS, the main by-product of the activity.

The second configuration includes a “biogas production unit” generating “green” electricity and heat out of pulp top shoots and stillage from sugar-beet. In this case steam and electricity previously bought are self-generated within the plant, whereas pulp is not sold anymore since it is used in the biogas unit.

4. Methodology and model specification

Models for optimisation of bio-energy conversion seek to determine plant size and technology. Detailed information is included on capital and administrative costs (which decrease with plant size), on variable conversion costs (proportional to the output), as well as on transport costs (increasing with plant size). Raw material costs are often assumed proportional to the output and biomass price is perfectly elastic thus constant no matter the quantity demanded by the plant. In other words, agriculture is not given special attention assuming that production is undertaken in homogeneous land and farm structures. A typical example of this engineering approach is a model by Nguyen and Price [14] on bio-ethanol from sugarcane and sweet sorghum in Australia. Analysis is sufficiently complicated concerning conversion using single or mixed crops and various transport costs, resulting in optimal ranges of size of the conversion plant. With regard to biomass raw material, cane and sweet sorghum prices and yields used are constant, assuming a simplified view of the agricultural supply.

Partial equilibrium micro-economic models are used to improve representation of the farm sector in agro-industry models and the introduction of energy crops in the crop mix. For example, Treguer and Sourie[15] have estimated the agricultural surplus generated by the production of energy crops including sugar beet-to-ethanol, and assessed how these new crops can help to maintain farmers’ income and farms’ structure. Rozakis and Sourie[16] built a partial equilibrium economic model in order to assist in the micro-economic analyses of the multi-chain system of the biofuel chain in France.

On this track, the present study aims at evaluating the conversion of a sugar factory to an ethanol production plant. It pays special attention to the fact that biomass cost increases with higher demand and also that capital costs per unit of output fall in bigger plants. Partial equilibrium agricultural sector modeling and engineering approaches, applied to the industrial model, are jointly exploited to determine the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply. The most efficient farmers will provide beet and grain at the lowest possible prices.

More specifically agriculture and industrial production are coupled in the frame of an integrated model actually containing two sub-models, namely the agricultural supply model and the ethanol production unit model. In the agricultural model, a large number of individual farms are articulated so that to adequately represent regional arable agriculture. Each farm selects a set of activities (cropping plan) in order to maximize gross margin. The farm planning is governed by resource availability, technical and policy constraints. Main constraints are:

available land (both total land area and area by land type such as irrigated, non irrigated etc.), irrigation water availability constraints, crop rotational constraints, environmental constraints, and so forth.

The demand curve for most crops is assumed to be perfectly elastic, i.e., the price of the crop assumed to be fixed and determined exogenously. This is a strong hypothesis that does not hold in the case of alfalfa. The demand curve of alfalfa has a negative slope, because this commodity is bulky and long-distance transport becomes complicated, so that its price is determined in the domestic market. There is a limit of quantity that can be sold in the domestic market, and demand depends on the quantity of ruminant livestock that consume it. Thus the agricultural supply model contains one quadratic term in the objective function.

Profit maximization of the industrial unit determines the optimal size and technical configuration of the plant, giving maximum income from sales of product and by-products and minimal cost of production. The main relationships shaping the feasible area of the industry model deal with capacity, sugar-beet to wheat ratio to ensure maximal duration of operation during the year (330 days), and capital cost linked to size (average capital cost is decreasing for increasing ethanol capacities). Usually size determination is modeled by binary or integer variables, as in a bio-energy application[17] that also mentions a number of studies of the same kind. In this study, since a continuous relationship is available[18] we preferred to introduce exponential terms (scale coefficients) in the objective function rendering the industrial module non-linear also. Furthermore, feedstock supply i.e., wheat and sugar beet produced in farms, have to satisfy industry needs (raw material demand should be greater than supply). A number of balance constraints concerning by-products, material inputs and environmental indices (such as water for irrigation) complete the constraint structure.

The integrated model combines both agricultural and industry objectives as its objective function represents total surplus that is equal to the sum of industry and agricultural sector surpluses. It is written in GAMS code and uses non-linear solvers. Algebraic notation of model constraints and objective function along with associated indices, parameters and decision variables are detailed in the appendix.

5. Case study

5.1. Agricultural Sector

It is assumed that farms holding sugar-beet quota and possessing considerable experience on its cultivation (since they had multi-year contracts with the sugar industry) will be the first and presumably most efficient suppliers of the ethanol plant with beet. The reason for choosing cotton cultivating farms beside sugar-beet is that an enormous number of farms cultivate this staple crop in the region. In order to ensure profitability for the ethanol plant it is important to spread capital and administrative charges over a longer period. It points out to the attractiveness of using mixed crops, in this case beet and grains, to extend the processing season that can thus count 330 days per year. The cultivation of irrigated wheat is considered to supply ethanol plant by grains, first because output is much higher than that of non-irrigated wheat, soft or hard, and secondly because it means extensive cotton cultivation replacing monoculture with cotton-wheat rotation[19].

In the present study we use data on farm structure, costs and yields from 2001-2002, i.e., under the old CAP is considered (scenario 1) then changes of CAP, i.e., new CAP element like decoupling of aid and cross compliance are introduced then in the model (scenario 2). Farms which cultivated at least one stremma (one tenth of a hectare) of cotton or at least one with sugar beet for the farming period 2001-2002 were selected for the study. A group of 344 arable farms out of all farms monitored by the Farm Accountant Data Network (FADN) satisfy the above constraint, representing in total 22,845 farms of the region.

The main crops cultivated by those farms are: Soft wheat, Hard wheat, Irrigated wheat, Maize, Tobacco, Cotton, Dry cotton, Sugar beet, Tomato, Potato, Alfalfa, feedstock maize and intercropped vetch to conform with the cross compliance term of the new CAP. Data used for the particular crop and for each agricultural farm sample were: output (kg/acre), prices (€), subsidy (€/kg and €/acre depending on the type of crop) and the variable costs (€/acre). Variable cost includes: Seeds and seedlings purchased, fertilizers and soil amelioratives, protection chemicals, fuels and lubricants, electrical energy, water, running maintenance of equipment, maintenance of buildings and landed improvements, salaries and social taxes, and wages of hired labour.

In figure 1, one can observe surfaces cultivated at the regional level by main crops in the base year 2002 as well as the optimal cropping plan for scenario 1 (CAP 2000). Model optimal results approach closely to observed surfaces forming a validation test proving the selected model specification can be used to perform predictions of the farmers' behavior under different parameters' sets. A national model of similar structure[20] passed successfully the validation test that increases confidence on non-linear sector models of Greek arable cropping systems. As a matter of fact, in the optimal solution when the model runs under the CAP 2003 regime (scenario 2) cotton cultivation is significantly decreased, replaced by maize, alfalfa and soft wheat. Also sugar beet almost disappears due to drastic price reductions.

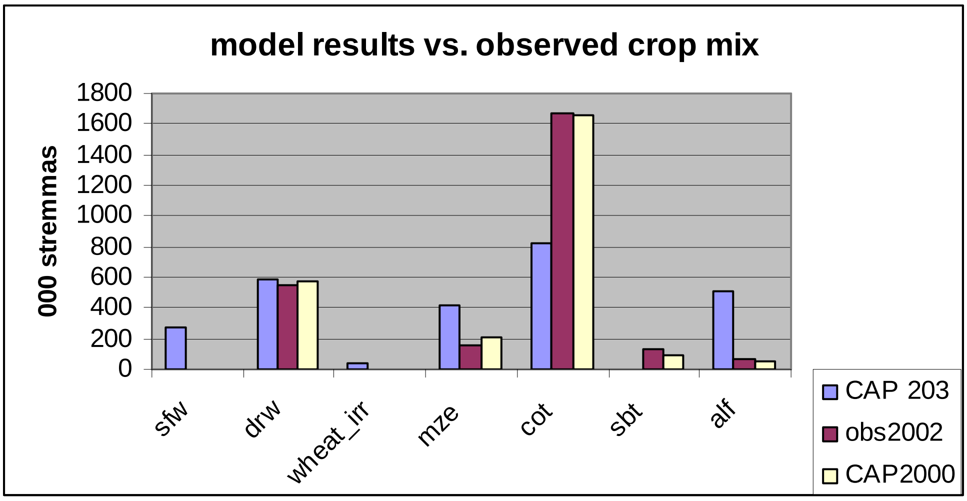

Figure 1. Observed and optimal crop surfaces at the regional level

5.2. Industry

Technical and economic data for the production process of ethanol and determination of various costs for the industry model are drilled by Soldatos and Kallivroussis[18] adapted to the conditions of ex-sugar factory in Thessaly by Maki [21]. Data include a transformation ratio from wheat and sugar beet to ethanol, corresponding prices and required quantities (per produced quantity of ethanol) of additional and auxiliary matters e.g. chemical substances, the requirements in electrical energy and steam and the corresponding costs, production rate of by-products and the sale prices of produced ethanol and by-products.

The base capacity of the unit (35000 t EtOH) determines the cost of investment, the cost of equipment, the requirements for the workforce and a line from costs (direct and indirect) that concerned the economic analysis as well as a pattern of the final cost of the first and auxiliary matters, the cost of electrical energy and steam, the cost of maintenance and other costs of operations that concern the production and the administrative support of the unit. A scale coefficient of 0.61 is used in an exponential function linking capital costs to plant capacity. Allowable range of capacities vary from 10000 to 120000 t. Capital costs are shown in Figure 2 illustrating a decreasing rate of increase of capital costs with increasing scale. This means decreasing average capital costs are associated with larger ethanol plants.

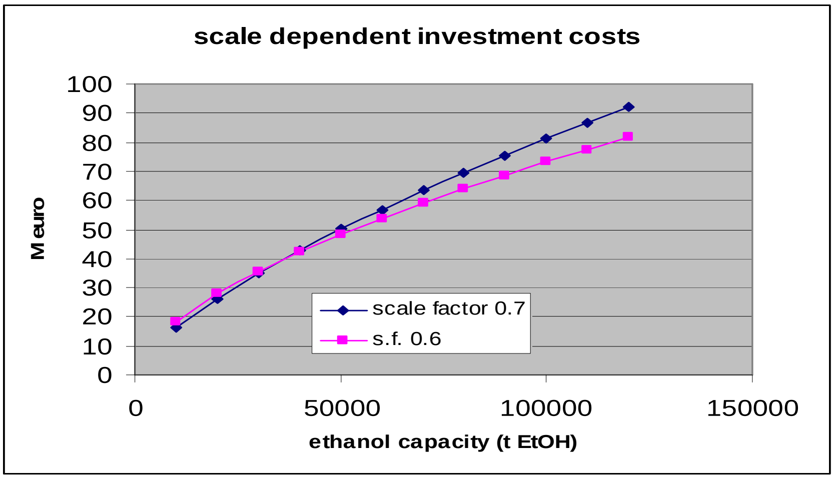

Figure 2. Investment cost of ethanol plant

6. Results and discussion

Parametric optimization of the integrated agro-industrial model determined the optimal crop mix for farmers as well as the best technology configuration for the industry and size of the plant. As expected, biomass costs increase and transformation costs decrease with capacity in any case. Biomass costs are endogenously given by the model (dual prices) resulting from changes in the crop mix to satisfy the increasing biomass demand from the industry. In figure 3 the evolution of optimal crop mix at the regional level for increasing ethanol plant sizes is presented, starting from the CAP 2003 optimal solution (for zero ethanol production presented in bar form in figure 2). Figures 4 and 5 illustrate results for capacities from 30 to 120 thousand tons of ethanol. All magnitudes are reported in average values per ton of ethanol.

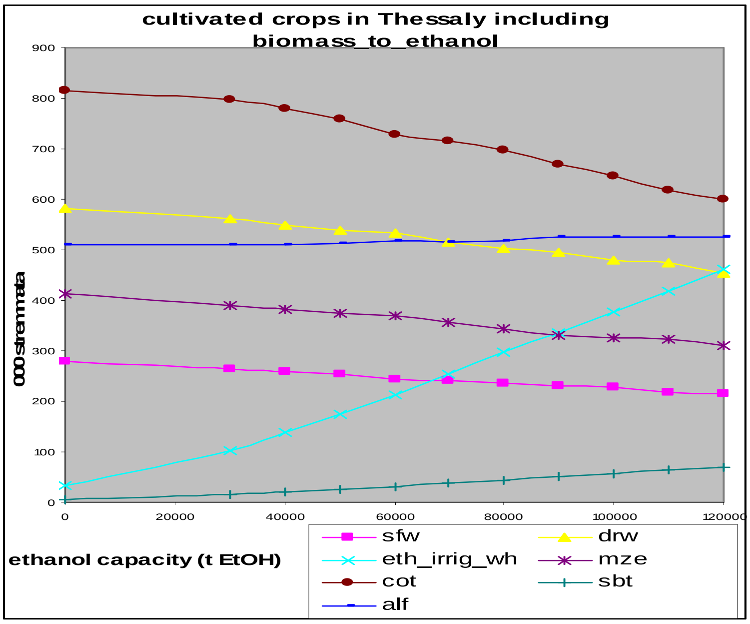

Figure 3. Evolution of cultivated surfaces by main food and energy crops.

Outflows (costs) consist of raw material costs (sugar beet and wheat), other variable input and labour cost as well as capital costs. Raw material cost is determined by the dual values of biomass demand satisfaction constraints for both energy crops, multiplied by respective quantities. The model maximizes total profits, thus it proposes the highest possible capacity. If we maximize average profit (profit per ton of ethanol) then lower than 120000 ton capacities are preferred although average profit is almost stable.

Key results of the model concerning the original configuration are presented in figure 4. One can observe that average costs always exceed average inflows. Total average cost is minimized in capacity range of 50-60 kt ethanol. Explicitly, average capital costs begin at 247 euro/t for small plants (30000 t) and decrease to 144 euro/t for maximal capacity (120000 t). Other variable costs (comprising labour and administrative expenses, chemical inputs and steam and electrical energy) start from a similar level for the small plant (249 euro/t), but unlike average capital costs they remain almost at the same level per unit for higher capacities (240 euro/t in 120000 t). Sugar-beet and wheat amount at almost 50% of total cost for small plants but this element increases to 57% for 120000 t plant.

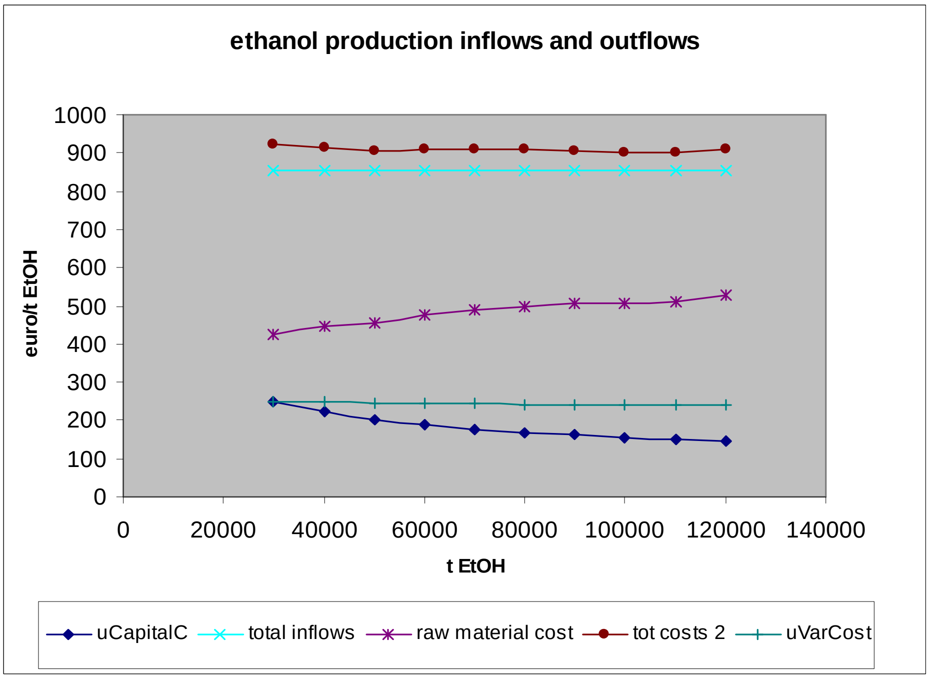

Figure 4. Inflows and outflows per unit of ethanol (configuration 1)

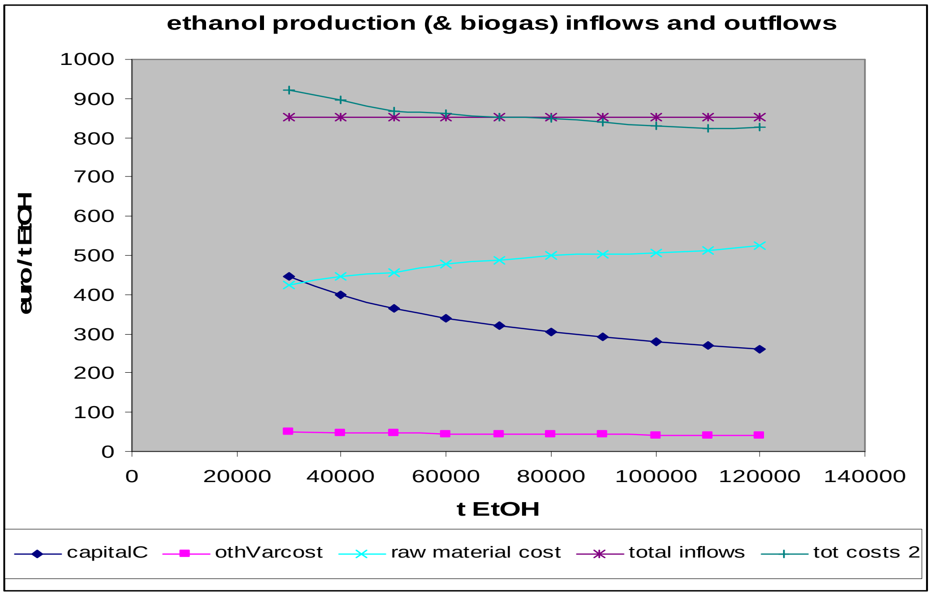

Figure 5. Inflows and outflows per unit of ethanol (configuration 2)

Concerning the configuration of ethanol plant with its own biogas facility results are considerably better, and they are presented in figure 5. Average cost curb intersects average inflows for plants up to 70000 t capacity. Capital costs are higher, as they incorporate investment cost of biogas unit beginning from 446 euro/t for small plants (30000 t) although rapidly decreasing to 260 euro/t for maximal capacity (120000 t). Other variable costs (which now only comprise labour and administrative expenses and chemical inputs as heat and electricity are produced by the biogas unit) start from a much lower level of 51 euro/t for the small plant and they decrease to 41 euro/t for higher capacities (120000 t). Sugar-beet and wheat amount at 46% of total cost for low quantities (small plant) but their part increases to 63% for the maximal capacity 120000 t plant. Maximum average and total profit is observed at the level of 120 000 tons, thus determining the optimal size of the plant.

7. Conclusions

This paper attempts an economic evaluation of bio-ethanol production in the context of the ex-sugar industry in Thessaly taking into consideration recent changes in the Common Market Organization for sugar in the E.U. and options considered by the Hellenic Sugar Industries.

It is assumed that industry uses both beet and grains to produce ethanol thus spreading fixed charges over greater production volume. An alternative scheme has also been evaluated where a biogas production unit consuming fermentation by-product satisfies the energy needs of the plant.

An integrated model articulating agricultural supply of biomass with its processing to ethanol maximizing total surplus determines the optimal production level. A plant configuration including abiogas facility proves to be more successful from an economic point of view. A plant of 120 kt ethanol represents optimal plant capacity, and is the highest one in the examined range.

Further research should be conducted to take into account uncertainty[16]. Uncertainty issues concerning not only demand side (ethanol and by-products price volatility) but also supply side (changing policy contexts and competitive crop price volatility) need to be addressed in order to determine ethanol profitability confidence levels. Also additional technical configurations including recent research findings on promising crops such as sorghum[21] could increase farmers' gains.

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9. Appendix

Mathematical specification of the Model

Indices:	j	Crops: {sfw: Soft Wheat, drw: Hard Wheat, wir: Irrigated Wheat, mze: Maize, mzf: Maize for fodder, tob: Tobacco, cot: Cotton, cotd: Dry Cotton, sbt: Sugar Beet, tom: Tomato, pot: Potato, alf: Alfalfa, vik: Intercropped vetch }
	k	Crop(s) having demand curve with negative slope
	r	Irrigated crops: {tob, cot, mzf, wir, pot, sbt, tom, mze, alf, cot}
	rot	Rotational crops: {mze, mzf, tob, sbt, cot, tom}
	$eth, ddgs, plp$	Ethanol, DDGS: Dried Distillers Grains with Soluble, Pulp

Model parameters:

p_j	Price of crop j
y_j	Yield of crop j
s_j	Subsidy on output of crop j
sub_j	Subsidy on area cultivated by the crop j
v_j	Variable cost of crop j
$P_{\{eth, ddgs, plp)}$	Price of ethanol, Distilled Dry Grain Solubles (DDGS), pulp
X	Total cultivable land surface of the farm
X_r	Available irrigated land area of the farm
w_f	Weight of farm
rot_coeff	Rotational coefficient
dec_surf	Decoupling surface
wt_j	Water requirement for crop j
wt_f	Water capacity of farm
wt_t	Total water quantity of the region
tr_{eth_wir}	Transformation rate from wheat to ethanol
tr_{eth_sbt}	Transformation rate from sugar beet to ethanol
q_{eth_base}	Reference capacity of 35000 tonnes

Decision variables:

x_j	Area cultivated by crop
$Q_{\{sbt, wir\}}$	Demand for sugar beet or wheat
$q_{\{eth\_wir, eth\_sbt\}}$	Quantity of ethanol produced from wheat or sugar-beet
$q_{\{eth, ddgs, plp\}}$	Total quantity of ethanol, DDGS or pulp produced in a year
tc_{ind}	Annual total cost of the industry

Objective: Maximization of Total Profit
The objective function of the integrated model is:

$$Max\sum_{j=1}^{n}((p_j+s_j)y_j+sub_j-v_j)x_j+\sum_{k=1}^{t}((\alpha-\beta\Sigma w y_k x_k)y_k-v_k)x_k+p_{eth}*q_{eth}+p_{ddgs}*q_{ddgs}+p_{plp}*q_{plp}-tc_{ind} \tag{1}$$

<u>Subject to resource constraints:</u>

Land constraint: Cultivated area may not exceed the total cultivable land area of the farm.

$$\sum_{j=1}^{n}x_j-x_{vik}\leq X \tag{2}$$

Irrigated land area constraints: Irrigated crops area may not exceed 10% more as of the total irrigated land area of the farm in 2002.

$$\sum x_r \leq 1.1 * X_r \tag{3}$$

Irrigation constrained: Water demand of the farm may not exceed to the water capacity (actual quantity) of the farm.

$$\sum wt_j * x_j \leq wt_f \tag{4}$$

Regional water constraint: Water demand for all farms of the region equal to the total water quantity of the region.

$$\sum f \sum wt_j * x_j = wt_t \tag{5}$$

Subject to quota constraints:

Constraint on cotton, sugar-beet and tobacco area: Crop area may not exceed areas cultivated cotton in 2002.

$$X_{crop} \leq coeff * X_{crop2002} \tag{6}$$

Subject to flexibility constraints:

Maize for fodder area constraint: Fodder maize cultivation area may not exceed by three times of maize cultivated area for fodder in 2002.

$$x_{mzf} \leq 3 * x_{mzf2002} \tag{7}$$

Potato cultivation area constraints: Potato cultivation area may not exceed 10% more as of the total potato cultivated area of the farm in 2002.

$$x_{pot} \leq 1.1 * x_{pot2002} \tag{8}$$

Tomato cultivation area constraints: Tomato cultivation area may not exceed 10% more as of the total tomato cultivated area of the farm in 2002.

$$x_{tom} \leq 1.1 * x_{tom2002} \tag{9}$$

Subject to environmental and policy constraints:

Constraints on alfalfa rotation area: Alfalfa area may not exceed rotational coefficient times total rotational cropped area.

$$x_{alf} \leq rot\_coeff * \sum x_{rot} \tag{10}$$

Environmental constraints: Rotational vetch cultivation may not less then decoupling surface deduced by alfalfa and multiplied by obligatory percentage.

$$x_{vik} \geq obligatorypercentage * (dec\_surf - x_{alf}) \tag{11}$$

<u>Subject to biomass demand and supply constraints:</u>

Wheat (sugar-beet) supply constraint: Wheat (sugar-beet) demand by the industry may not exceed the total supply of wheat (sugar-beet).

$$q_{wir} \leq \sum f \sum w * y_{wir} * x_{wir} \tag{12}$$

$$q_{sbt} \leq \sum f \sum w * y_{sbt} * x_{sbt} \tag{13}$$

<u>Balance constraints:</u>

Total quantity of ethanol will be equal to the sum of quantity ethanol produced from wheat and quantity ethanol produced from sugar beet.

$$q_{eth} = q_{eth\_wir} + q_{eth\_sbt} = tr_{eth\_wir} * q_{wir} + tr_{eth\_sbt} * q_{sbt} \tag{14}$$

Total quantity of DDGS will be equal to the demand of wheat multiplied by transformation rate from wheat to DDGS.

$$q_{ddgs} = tr_{ddgs\_wir} * q_{wir} \tag{15}$$

Total quantity of pulp will be equal to the demand of sugar beet multiplied by transformation rate from sugar beet to pulp.

$$q_{plp} = tr_{plp\_sbt} * q_{sbt} \tag{16}$$

<u>Industry technical constraints:</u>

Total capital cost is derived from expected capacity divided by reference capacity (35 000 t) exponent by scale factor (0.61) and multiplied by reference investment cost (12.4 M Euro) and accumulated other investment cost factor (3.41).

$$TotalCapitalCost = 3.41 \cdot \left(q_{eth} / q_{eth\_base}\right)^{0.61} \cdot 12.4 \tag{17}$$

Plant capacity constraint: Annual capacity of ethanol production of the plant (size of the plant) assumed to be between 10000 and 120000 ton.

$$10000 \geq q_{eth} \leq 120000 \tag{18}$$

An integrated model to evaluate bio-energy production in the sugar industry and the cost of CO_2 saving

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Objectives

Converting the sugar industry to bio-ethanol production may create opportunities for sustainable management of the existing industry infrastructure and also serve bio-fuel policy targets. The purpose of the study is to evaluate conversion of a sugar factory to an ethanol production plant in Thessaly, Greece, concerning economic and environmental aspects.

Integrated model for bio-ethanol chain

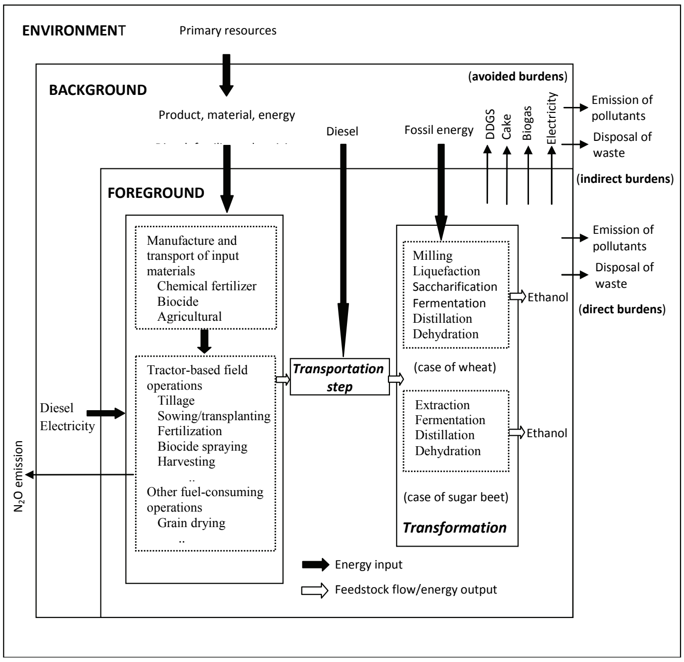
Partial equilibrium sector modeling maximizing simultaneously welfare in agriculture and industry is used for this purpose. Agricultural feedstock supply and industrial processing sub-models are articulated indicating optimal crop mix for farmers and the best technology configurations for industry. Sugar beet and wheat is considered as raw material for ethanol production.

LCA methodology

Environmental performance is assessed under the Life Cycle Assessment (LCA) framework. The purpose of LCA is to study the environmental impacts of a product or a service from the 'cradle' to the 'grave'.

Integrating economic and environmental models: LCAA

Mathematical programming techniques of production activities applicable to a sector i.e., activity analysis (AA) and the life cycle assessment are coupled to build the life cycle activity analysis (LCAA) modeling methodology.



ENVIRONMENT
Primary resources
BACKGROUND
(avoided burdens)
Product, material, energy
Diesel
Fossil energy
DDGS
Cake
Biogas
Electricity
Emission of pollutants
Disposal of waste
(indirect burdens)
FOREGROUND
Manufacture and transport of input materials
Chemical fertilizer
Biocide
Agricultural
Tractor-based field operations
Tillage
Sowing/transplanting
Fertilization
Biocide spraying
Harvesting
..
Other fuel-consuming operations
Grain drying
..
Diesel
Electricity
N_2O emission
Transportation step
Milling
Liquefaction
Saccharification
Fermentation
Distillation
Dehydration
Ethanol
(case of wheat)
Extraction
Fermentation
Distillation
Dehydration
Ethanol
(case of sugar beet)
Transformation
Emission of pollutants
Disposal of waste
(direct burdens)
Energy input
Feedstock flow/energy output

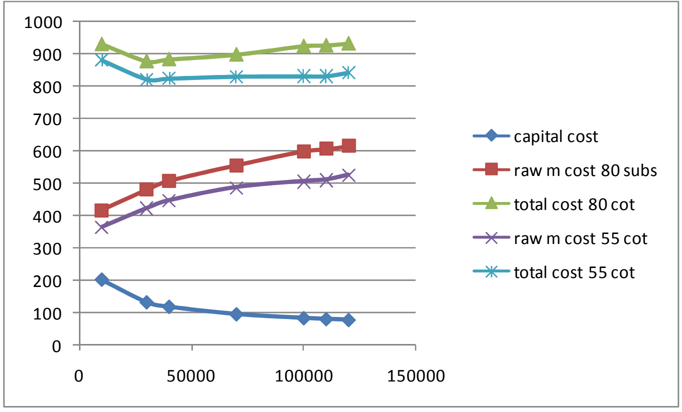
Case study in Thessaly, Greece

According to the Sugar Market Organization reform less competitive EU members have been incited to reduce produced volume. Greece has decided to cut half of the national quota by converting two out of five industrial plants, one of them was located in Larissa in the Thessaly region. Energy crops for ethanol considered are sugar beet and secondly wheat cultivated mainly in two types of arable crop farms: sugar-beet producing exploitations and cotton oriented exploitations. Farm Accounting Data Network (FADN) data on number of farms per type (in total 344 representative farms), surfaces cultivated, and land set aside concerning the above farm types have been used in this exercise along with detailed data on inputs of arable crops used by each farm.

Model results

Results estimate costs and profits. Biomass cost is so important that changes in agricultural policies affect bio-ethanol accounts. For instance higher area payment for cotton increase the energy crops opportunity cost resulting in higher ethanol costs. Figure 1 shows that optimum crop mix suggested maximum plant size in the considered range for profit maximization. Plant capacity of 30 kt of ethanol production per year was found the most cost-efficient plant size. If receipts per EtOH ton (including by-products) exceed 900 euro then the optimal size may reach much higher capacity.

Figure 1. Main ethanol cost items (capital and biomass cost) and total costs in euro/t by capacity (kt) for two cotton subsidy levels (55 and 80 euro/ha)



Environmental performance analysis showed that CO_2 emission is reduced both in agricultural sector by modeled crop mix and replacing gasoline by ethanol but CO_2 saving is appeared to be expensive. A joint ethanol-biogas option appears to be preferable in terms of both economic and environmental aspects. Substantial amount of CO_2 emission could be avoided using biogas based (electricity generated from biogas) industrial processing and thus cost of CO_2 saving is reduced.

Table 1 GHG emission in the ethanol production system (in kt CO_2eq)

Scenario 1 : area payment for cotton @ 55(€/ha) CAP 2003
Scenario 2 : area payment for cotton @ 80(€ /ha) CAP 2008

EtOH plant configuration	Without Biogas Plant				With Biogas Plant			
GHG emissions direct and iLUC	Scenario 1			Scen 2	Scenario 1			Scen 2
Plant size (kt)	60	90	120	79.42	60	90	120	53.12
CO_2 emission (agri+trans) considering direct land use change (LUC): only wheat & sug beet pdn	26.3	41.6	57.1	36.4	26.3	41.6	57.1	23.5
CO_2 emission (agri+trans) indirect land use change (iLUC)	-20.1	-33.1	-44.2	-18.9	-20.1	-33.1	-44.2	-9.7
CO_2 emission (agri+trans) indirect land use change (iLUC) for import	30.1	49.7	62.6	22.0	30.1	49.6	62.6	12.7
CO_2 avoid_reduc_soy cake_imp	-31.7	-47.5	-63.4	-41.9	-	-	-	-
Total net CO_2_import_iLUC	-1.5	2.1	-0.7	-19.9	30.1	49.6	62.6	12.7
CO_2 at industrial transformation								
CO_2 for electricity	15.6	23.3	31.1	20.6	-3.0	-4.5	-6.0	-2.5
CO_2 for steam	71.9	107.8	143.8	95.1	71.9	107.8	143.8	63
Total CO_2 industrial processing	87.4	131.2	174.9	115.7	68.9	103.3	137.7	61.1
CO_2 gasoline to be replace	-151.3	-226.9	-302.6	-200.3	-151.3	-226.0	-302.6	-133
Total net CO_2eq emission in different LUC boundaries								
Total net CO_2 direct LUC (save)	-37.5	-54.2	-70.6	-48.1	-56.1	-82.0	-107.7	-33.4
Total net CO_2_regional_iLUC	-83.9	-128.9	-171.9	-103.5	-102.5	-156.7	-209.0	-66.2
Total net CO_2 incl.import_iLUC	-85.4	-126.8	-172.6	-123.4	-72.3	-107.1	-146.4	-53
Total net CO_2eq per ton of ethanol (t)								
Net CO_2 direct LUC per t eth	-0.626	-0.602	-0.588	-0.605	-0.936	-0.911	-0.898	-0.621
Net CO_2_reg_iLUC per t ethanol	-1.398	-1.432	-1.432	-1.303	-1.708	-1.742	-1.742	-1.2
Net CO_2 incl.impt_iLUC per t eth	-1.424	-1.409	-1.438	-1.554	-1.205	-1.190	-1.220	-1.01

Enhancing Web-Spatial DSS interactivity with parallel computing: The case of bio-energy economic assessment in Greece[1]

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Abstract

A web based Spatial Decision Support System (web SDSS) has been implemented in Thessaly, the most significant arable cropping region in Greece, in order to evaluate selected energy crop supply. The web SDSS uses an optimization module to support the decision process, incorporating user input from the web user interface then launching mathematical programming profit maximizing farm models.

Energy to biomass raw material cost is provided in supply curve form incorporating physical land suitability for crops, farm structure and Common Agricultural Policy (CAP) scenarios. In order to generate biomass supply curves the optimization problem is parametrically solved for a number of steps within a price range determined by the user. The more advanced technique used to solve the MP model, the higher the delay of response to the user.

We are examining how effectively we can reduce the web SDSS response time to the user requests using parallel solving of the corresponding optimization problem. The results are encouraging, as the total solution time drops significantly as the problem's size is increased, improving the users' experience.

KEYWORDS

Web Spatial Decision Support System, Parallel Computing, Mathematical Programming, Energy Crop Supply.

1. INTRODUCTION

The progress in Web-based decision support technologies has been recently described by Bhargava et al. (2007) who distinguish between model-driven and data-driven decision support system (DSS) to provide an impressive list of systems for decision support using the web as a medium (stand-alone commercial applications) or as a computer (web-DSS). Most applications concern business decision support, whereas some deal with environmental issues involving also multi-criteria models often attempting to enhance public participation in local environmental decision making (Kingston et al., 2000). One of the most interesting classes of web-based decision support tools are the so-called Spatial DSS (SDSS). SDSS as defined by Sugumaran & Sugumaran (2005) are "flexibly integrated systems built on a GIS platform to deal with spatial data and manipulations, along with an analysis module ... they support 'what if' analysis ... and help the user in understanding the results". With the development of the internet, Web-based SDSS have been developed, adding Internet interface programs to the computational models and geographic databases of the SDSS, in order to provide decision support through the Web based on relevant information.

Bio-energy issues constitute by excellence spatially dependent problems requiring both detailed spatial information but also extensive model building. Unlike conventional energy carriers that have hierarchical structure, biomass-to-energy production involves hundreds to often thousands of decentralised decision makers. This is considered one of the "grand challenges" for bio-energy assessment (McKone et al., 2011). As a matter of fact bio-energy profitability is linked to the structure and perspectives of the arable cropping

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systems to supply considerable quantities of a bulky raw material to transformation plants also taking into account demand location and volume. Recent analyses of economic biomass potential are reported in regional (Hilst et al., 2010) or country level (Simon et al., 2010). Therefore, appropriate tools are necessary to enable comprehensive analysis and support decisions of policy makers, industry, researchers and farmers. For this purpose, a state-of-the-art modular SDSS that contains optimization models fed by technical, economic, and cartographic databases has been built to provide stakeholders with region specific biomass-to-energy supply information in Central Greece (Rozakis, 2010). Optimization software is embedded in a GIS environment allowing for an interactive process in real time. A web-based interface built in open source software makes the SDSS tool available for collaborative decision-making. The tool operates on the Internet where the user can have access to the data set, enter selected parameters into the model, and enables spatial visualisation and exploration of the results, injecting interactivity in the decision process.

Numerous gross margin maximizing Decision-Making Units (DMU), geographically dispersed decide whether or not to introduce energy crops in their crop mix using crop suitability maps and survey data at the farm level. Mathematical programming models of a large number of representative farms are articulated and parametric optimization is used to generate supply curves for the energy crops at the regional level. Similar bottom-up mathematical programming models have been used to estimate agricultural policy impacts and farmers' supply response. Conventional linear programming is gradually being dominated in the agricultural economics literature by alternative methods such as multi-criteria (Manos et al. 2009) or interval linear programming (Rozakis, 2011) models and also positive models incorporating downward sloping demand (Rozakis et al., 2008) or increasing cost functions (Petsakos and Rozakis, 2010) in the objective function. These methods, broadening economic rationality, manage to transform the objective function so that optimal solutions include not only crop plans on the vertices of the feasible polyhedron but also points on hyper-plans enabling the model to approach observed levels of activities, thus outperforming their LP counterparts. Nevertheless there is a price to pay that is the increased complexity and consequently solution time span of such models. That may not be a problem when models are operated for research purposes, but it certainly is a serious drawback in business oriented environments and especially in a context of interactive decision making such as the one previously described.

Farm models articulated in an angular structure are parametrically solved to explicit supply response to bio-energy market signals, in other words optimisation is consecutively launched for different entry data. This results in numerous independent problems that may handily be set in parallel identifying to the embarrassing parallelism question as each iterative solution is independent to anyone else. This feature makes the parallel solving off such problems quite interesting since lapse time for resolution is drastically shrunk. Furthermore, the extensive use of Personal Computers (PCs) within the scientific community and tremendous increase in their CPU's frequency, and the advent of multi-core CPUs and network technologies (intranets and internet) has rendered distributed computing infrastructures readily accessible even to modest research institutes (Creel 2005).

Parallel computing is implemented in this paper aiming at improving efficiency of the optimization process in the bio-energy assessment web-SDSS. Next section introduces the concept of parallel computing in the case of web accessible Decision Support Systems. Section 3 presents the methodology of the optimization component and the model specification for arable agriculture in Thessaly, Greece. Model parallelization, the implementation issues and the speedup results for a case study of integrating a web-SDSS with a parallel LP meta-solver follow in section 4. The paper is completed by concluding remarks and issues of further research work.

2. PARALLEL COMPUTING FOR MODEL-DRIVEN WEB-DSS BODY OF PAPER

Web-Based DSS deliver decision support information or decision support tools using a "thin-client", that is a Web browser. A model-driven web-DSS such as the one supporting biomass assessment, according to the typology of Power (via Bhargava, ref. 44-45) "use formal representations of decision models and provide analytical support using tools of decision analysis, optimization, stochastic modeling, simulation, statistics and logic modeling". A model-driven web-DSS should contain at least two components: The user interface component, which would be some kind of web application and the decision analysis component that would include the necessary software that will perform the decision analysis. The former component is the front-end which the user interacts with the web-DSS by feeding input to the latter component and obtaining results from it.

Tolerable waiting time (TWT) is defined as the amount of time users are willing to wait before giving up on the download of the web page. There are several papers that attempt to measure TWT with time spans ranging from 4 to 41 seconds (Nah, 2004). For a web-DSS the above time values should not be considered literally, since the user is more dedicated to the purpose of obtaining the results(that is downloading the web page) than a user browsing or querying various sites. However the above results give us an order of magnitude of the time a web-DSS system should respond and that it should not exceed one minute. Also it is deducted that for the same web-DSS, as the waiting time decreases, the user experience is improved and enriched.

Given the high possibility that the computation procedures might be a major source of delaying the system's response, we are looking for ways to decrease this delay. Implementing parallel computing algorithms to our decision analysis can give us a solution to the above problem. There are cases where solving the decision problem in parallel is embarrassingly easy, for example when the decision process incorporates solving a Monte Carlo simulation, performing sensitivity analysis, solving different scenarios or when we have to solve multiple independent linear problems.

Migrating from an existing (serial) decision analysis component of a web-DSS to a parallel solution is not a trivial task since several issues have to be resolved. For example we are primarily concerned about the immediate distributed resources availability. A system like Condor (http://www.cs.wisc.edu/condor/) cannot guarantee a real-time response of the web-DSS as there might be times that our requests will be batched instead of processed immediately. There is also an issue about the cost-benefit ratio of migrating to a parallel solution. The costs of adapting the serial implementation of the decision analysis process to a parallel system can be significant and for example it could include the development and the deployment of the software solution, the maintenance costs of the cluster, etc. On the other hand the benefit of using a parallel system is the decrease in the user waiting time, and this is greater as the problem size is increasing.

3. METHODOLOGY FOR ESTIMATING BIOMASS-TO-ENERGY SUPPLY

Mathematical programming models, maximizing profits under constraints, are articulated and parametric optimization is used to generate supply curves for the energy crops at the regional level. The elementary sub-model is specified as follows: an individual farm *(f)* is supposed to choose a cropping plan *(x^f)* and input use among technically feasible activity plans $A^f x^f \leq b^f$ so as to maximize gross margin gm^f. The optimization problem for the farmer f appears as:

$$\begin{cases} \max\limits_{x^f} gm^f\left(x^f, \theta^f, \kappa\right) \equiv g^f\left(\theta^f, \kappa\right) x^f \equiv \sum\limits_c \left(\left(p_c^f + s_c\right) y_c^f + sub_c - v_c^f\right) x_c^f \\ s.t.\_\_\ A^f\left(\theta^f, \kappa\right) x^f \leq b^f\left(\theta^f, \kappa\right)\_\_\_\ A \in \Re^{m \times n}\ \_(I) \\ x^f \geq 0\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ x \in \Re^n\ \_\_(II) \end{cases}$$

The sector model contains *f* farm problems such as the one specified above. The basic farm problem is linear with respect to x^f, the primal *n* × *1-vector* of the *n* cropping activities. The *m* × *n-matrix* A^f and the *m* × *1-vector* b^f represent respectively the technical coefficients and the capacities of the *m* constraints on production. The vector of parameters θ^f characterizes the f^{th} representative farm (y_c^f yields for crop *c*, v_c^f variable costs, p_c^f prices dependent on quality, s_c subsidies linked to crop quantity). κ stands for the vector of general economic parameters (*p* prices not dependent on farm, sub_c subsidies specific to crop cultivated area). The constraints can be distinguished in resource, agronomic, demand and policy ones. The model enables a comparative static analysis, but does not allow for farm expansion, as it takes as given land resource endowments and land rent of the base year. Different sets of parameters are applied to denote the policy context in vigor.

Unlike the standard linear programming formulation where input and output prices are assumed fixed and exogenous, price endogenous models are used in situations where this assumption is flawed or untenable. Usually the quantity of fodder crops produced affects the equilibrium price primarily due to the high transportation costs which restricts its consumption locally or to adjacent regions. As a result, and given the limited alternative uses of fodder crops, we assume that the price received by producers is determined by the total amount produced in the region. Price endogenous module for fodder crops renders the model quadratic (NLP), as specified in detail in Kampas et al. (2010).

To test how the constructed models can predict farmers' response to different market signals or policy shifts model builders perform validation process. For this purpose, observations for base year are compared to model results by examining appropriate distance measures. Among them the average absolute deviation (AAD) index is readily used, defined as the average absolute difference between the observed data and the land allocations generated by the model at the optimum: $\mathrm{AAD} = \frac{1}{I}\sum_{i=1}^{I}\left|x_i^{model} - x_i^{2006}\right|$

In order to generate reliable biomass supply curve to be used by the industry, different model specifications are validated so that the most efficient to approach the initial situation to be selected. Among the above mentioned specifications, non-linear programming usually results in much lower AAD index than its LP counterpart because it attenuates the penny switching nature of linear programming models.

4. CASE STUDY

A web based Spatial Decision Support System has been implemented in Thessaly, the most significant arable cropping region in Greece, in order to evaluate selected energy crop supply. The methodology and architecture of this tool are detailed by Rozakis (2010). Energy to biomass raw material cost is provided in supply curve form incorporating physical land suitability for crops (survey and spatial information), farm structure (survey) and Common Agricultural Policy (CAP) scenarios. State-of-the-art optimization software (GAMS) is embedded in a GIS environment allowing for an interactive process in real time. A web-based interface built in open source software makes the SDSS tool available for collaborative decision-making. Farm data of 344 representative farms based on European statistics (FADN) concerning production plans for year 2005 and 2006 completed by supplementary information collected by personal interviews with the farmers which also included detailed information about the value and quantity of agricultural inputs (i.e. water, fertilizers and pesticides), yields and subsidies per crop, land ownership, entitlements for the single payment regime, farm machinery and buildings, as well as specific information about human and machinery labor used per hectare for each crop and field operation.

Table 1. Aggregate results of crop area allocation (kha) and observed rotation for 2006

	LP	**NLP**	**Observed 2006**
Alfalfa	277.3	13.3	*11.9*
Cotton	284.8	468.7	*506.8*
D. Wheat	115.0	108.5	*168.4*
Maize	72.1	139.1	*48.8*
Peppers	7.4	7.4	*14.7*
Tobacco	0	0	*2.5*
Tomatoes	43.1	43.1	*34.1*
Set Aside	1.9	21.5	*27.8*
AAD index	*76.1*	*26.8*	

The LP model comprising 344 elementary sub-models estimates satisfactorily crop surfaces of secondary importance such as durum wheat, peppers and tomatoes as shown in Table 1. In contrast, it underestimates area to be cultivated by cotton by far the most significant crop in the region, at the same time overestimates maize (twice the observed area) and alfalfa (25 times the observed area!!). Alfalfa is becoming competitive versus previously high income crops such as cotton due to decoupling of subsidies from production. Thus the LP model allocates to this crop all land permitted by the constraints. In reality, the market mechanism is activated to decrease price so that the equilibrium to be attained in much less area cultivated (given in the last column of Table 1). The NLP specification, with the alfalfa inverse demand function, performs much better in predicting the 2006 situation, resulting in an average deviation of 26.8 hectares (AAD) in land coverage for each crop comparing with 76.1 for the LP model.

In order to generate biomass supply curves the optimization problem is parametrically solved for a number of steps within a price range determined by the user. Iterations for the serial solution for various steps for computing the supply curve are presented on table 2 for both LP and NLP models. One can observe that the NLP model requires remarkably higher time spans(order of magnitude of minutes instead of seconds) thus the analyst is obliged to consider trade-offs to facilitate decision process.

Table 2. Time lapse for parametric optimization of the regional model

Number of Steps	Solver	20	40	80	160
LP Time Elapsed in seconds	CPLEX	3	7	15	31
NLP Time elapsed in seconds	Conopt	56	140	321	602

This problem constitutes an embarrassing parallelizable Linear Programming problem (EPLPP) since it is comprised of numerous independent problems, that is, the elementary LP problem for a different price of the energy crop. EPLPP are good candidates for migrating to parallel solving because the communication overhead is minimal and the speedup can be maximum. There currently exist several alternatives for solving in parallel a LP model that is expressed in GAMS code, like GAMS Griding facility (Bussieck 2009) and Optimization Services (Fourer 2008). We have implemented an ad hoc solution that needs almost no change to the existing model code, epLPpMS and can operate efficiently in a small cluster like a PC-Lab in the Academia. epLPpMS means "embarrassing parallelizable Linear Programming problems Meta Solver". It is a master-worker architecture application that is written in Java and aims at solving embarrassingly parallelizable MP problems.

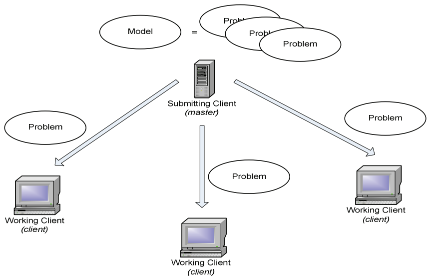

Figure 1. Architecture of epLPpMS

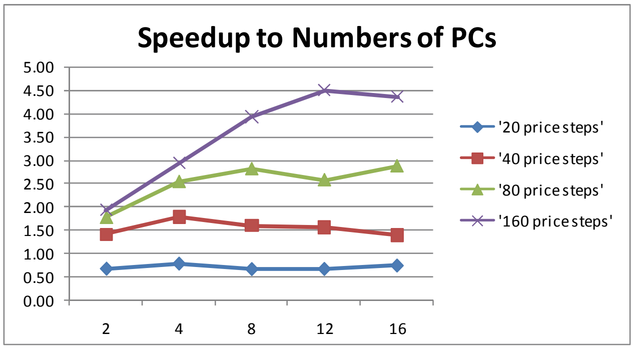

Figure 2. Solution Time Speedup to Number of PCs

Initially the model is transformed to the elementary problems that will be solved in parallel. Then these problems are transmitted to the worker machines that send the results back after the process of optimisation is completed. The user initiates the master process which is responsible for breaking the model in the multiple EPLP problems and also for their transmission to the remote worker processes. The worker processes are installed on the client machines located on the LAN and are responsible for solving the transmitted instances of the model.

After doing a minimal modification on GAMS model code and creating the appropriate xml input files we have run the web-DSS model in parallel. The operation took place at the Department of Agricultural Economics PC-Lab, where 20 windows workstations are currently in operation. Half of the PCs are Intel Pentium-4 2.3 MHz with 1Gb of RAM and the others are Intel Pentium Core-Duo 2.1 MHz with 512Gb of

RAM. The network topology is Ethernet at 100Mbs. We have collected the time elapsed for solving in parallel the LP model for 20,40,80,160 steps of a certain price range for energy crop at 2,4,8,12,16 PCs. We have run the test for each combination three times. The results are presented at table 3. Also the graphs of the speedup (the ratio of the serial solution time to the parallel solution time) to the number of PCs are presented on figure 2.

As we can see, for a small sized problem like 20 and 40 price steps the speedup is either a slowdown or insignificant. As the problem size is growing, like in the case of 160 price steps where a time of around 30 seconds is needed to solve serially the model, the speedup is significant and drops the solution time to 7 seconds, which is a tolerable waiting time for a web –DSS.

Table 3, Results for parallel solving time and computation speedup

price steps	no of pcs	time Run#1 in sec	time Run#2 in sec	time Run#3 in sec	Average time in sec	serial time in sec	speedup
20	2	3.58	5.07	4.60	4.42	3	0.68
20	4	4.54	3.29	3.68	3.83	3	0.78
20	8	4.18	3.85	5.41	4.48	3	0.67
20	12	5.63	3.85	3.88	4.45	3	0.67
20	16	3.93	3.86	4.33	4.04	3	0.74
40	2	4.94	4.98	4.99	4.97	7	1.41
40	4	4.29	3.56	3.91	3.92	7	1.79
40	8	4.40	4.43	4.29	4.37	7	1.60
40	12	4.51	4.67	4.28	4.48	7	1.56
40	16	3.62	6.34	5.14	5.03	7	1.39
80	2	8.78	8.18	8.42	8.46	15	1.77
80	4	5.97	5.75	6.00	5.90	15	2.54
80	8	5.50	5.15	5.34	5.33	15	2.81
80	12	5.11	6.52	5.84	5.82	15	2.58
80	16	5.34	5.03	5.28	5.22	15	2.88
160	2	16.86	15.39	15.89	16.05	31	1.93
160	4	11.03	10.41	10.23	10.56	31	2.94
160	8	8.37	7.45	7.86	7.89	31	3.93
160	12	7.21	6.59	6.91	6.90	31	4.49
160	16	7.36	6.91	7.04	7.10	31	4.36

5. CONCLUSION

Parallel computing is used to enhance the decision process quality regarding bio-energy projects evaluation. This is achieved thank to remarkable quantitative reduction in solution time of models that support decision making especially behavioral models that simulate farmers' response to prices signals emitted by the industry.

Improvement is significant in the case of LP models but results make a difference when demanding modeling specifications are built that overcome LP caveats and usually take the form of NLP models. Such models make the DSS tool more reliable able to survive in a business environment at a price of higher computing time duration. Parallel computing has proved that can palliate this problem making the web-SDSS tool more user friendly.

epLPpMS is currently implemented using an ad hoc configuration for the GAMS modeling environment but due to the flexibility of the object oriented nature of the JAVA programming language, there is a potential for extending the application to other modeling environment too. The description of how the model should be partitioned and what workstations are available as workers is given through an XML file. More information on the software can be found at http://aoatools.aua.gr/epLPpMS.

Further research is needed to accommodate the parallel computing algorithm in order to test advanced alternative model specifications representing state-of-the-art of regional modeling techniques, taking into account risk and uncertainty in farmer behavior as well as positive approaches to agricultural supply modeling. Finally several implementation and integration issues have to be addressed, like immediate distributed resource availability and the cost-benefit of migrating a system to a parallel system.

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Policy dependent CO_2 emissions of bio-ethanol in Greece: a consequential assessment using non-linear programming activity models

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According to recent reforms in the Common Agricultural Policy concerning the sugar regime, EU has encouraged less efficient member states to reduce domestic sugar production. At the same time, the European Commission considers transportation bio-fuels as a key factor for reducing reliance on imported fuels and emission levels of greenhouse gases. Matching the sugar sector with bio-ethanol production may create opportunities for sustainable management of the existing sugar industry infrastructure and also serve bio-fuel policy targets. The purpose of the study is to evaluate conversion of a sugar factory to an ethanol production plant in Thessaly, Greece, concerning economic, environmental and energy aspects.

Partial equilibrium sector modelling maximising welfare in agriculture and industry is used for this purpose. Agricultural feedstock supply and industrial processing sub-models are articulated indicating optimal crop mix for farmers and the best technology configurations for industry. Sugar beet and wheat is considered for feedstock for ethanol production. Environmental performance is assessed under Life Cycle Assessment framework.

Results show that optimum crop mix suggested maximum plant size in the considered range for profit maximization. Plant capacity of 120 kiloton of ethanol production per year was found optimum plant size. Environmental performance analysis showed that CO_2 emission is reduced both in agricultural sector by modelled crop mix and replacing gasoline by ethanol but CO_2 saving is appeared to be expensive. A joint ethanol-biogas option appears to be preferable in terms of both economic and environmental aspects. Substantial amount of CO_2 emission could be avoided using biogas based (heat and electricity generated from biogas) industrial processing and thus cost of CO_2 saving is reduced significantly.

Keywords**.** Sugar beet, wheat, ethanol, mathematical programming, life cycle assessment

1. Introduction

Renewable energy sources produced by the agricultural sector have been proven net contributors to the attenuation of the greenhouse effect by reducing the CO_2 emitted to the atmosphere when it substitutes for fossil energy. Biomass from plants emits, when transformed into energy as much as carbon dioxide as the one captured during the photosynthetic process of the plant growth plus emissions due to the energy consumed during the cultivation, collection, and delivery (agriculture) stage and the transformation (industry) stage of biofuel production. The overall net contribution to the reduction of anthropogenic greenhouse gas emissions made decision makers to pay particular attention and to support in some cases biofuel production. Especially when positive synergies with other public policy goals have been observed, governments have proceeded to support biofuels by applying tax exemptions so that the biofuels become competitive in the energy market. The above policy was coordinated to the CAP reform of 1992 that initiated the decoupling of aides to farmers from productivist practices, and biofuel activity gained momentum thank to a pivot element of the reform, namely the obligatory set aside measure not applied to energy and in general industrial crops.

Recent changes in European policies concerning the sugar and the bio-fuel sector, that complete Common Agricultural Policy (CAP) decoupling reform in 2003, create a favourable environment for ethanol production by ex-sugar factories in Europe. With changes in the EU sugar regime, and with WTO ruling, the Common Market Organization in the EU has excluded sugar and sugar beet for non-food use (sugar for the chemical and pharmaceutical industries and for energy purposes) from production quota restriction (EC, 2005). Several studies have been conducted to evaluate ethanol projects at the context of the sugar industry within the EU (Anonymous, 2006) but also in other countries facing similar conditions (Icoz et al., 2009).

Almost two decades after the take-off of the tax exemption program in Europe, bio-fuels are still more costly than fossil fuels and the agro-energy industrial activity largely depends on government subsidies for its viability. Even if the recent rise in crude oil prices alleviates the budgetary burden that bio-fuels represent, the question raised by economists concerning the efficient allocation of this amount among bio-fuel chains through tax exemptions to the bio-fuel processors is of primary importance. Nevertheless, environmental problems have become more acute and international commitments mean that the abatement of Greenhouse Gas (GHG) emissions requires intensified efforts. Assuming that biofuel main environmental positive effect is GHG emission reduction, the question arises as to whether subsidies for bio-fuels can be justified on cost effectiveness grounds. A recent study based on case study methodology for industry and supply modelling for agriculture has assessed GHG emissions cost-effectiveness regarding biodiesel production alternative schemes in Greece (Iliopoulos and Rozakis, 2010). In this paper, industrial transformation model is integrated to the agricultural supply model forming a sector model that estimates endogenously life cycle greenhouse gas emissions. Such integration of Activity Analysis - a well-known procedure in economics - with the environmental Life Cycle Assessment methodology, which aims to quantify the environmental impacts of a product from ‘cradle’ to ‘grave’, known as Life Cycle Activity Analysis (Freire and Thore, 2002) is used to evaluate the conversion of a sugar factory to an ethanol production plant in the region of Thessaly, Greece. (Rozakis et al., 2002) adopted this methodology to assist policy analysis concerning the multi-chain system of the biofuel industry in France.

Partial equilibrium agricultural sector modelling and engineering approaches, applied to the industrial model, are jointly exploited to determine the appropriate technical configuration and size of bio-ethanol plant, and at the same time raw material supply. The most efficient farmers will provide beet and grain at the lowest possible prices.

It is said that bioenergy is carbon neutral, that is carbon sequestered from the atmosphere during biomass growth is released when this biomass is used as a solid or liquid fuel after its transformation. However concerning biomass from dedicated energy crops, management requires energy and material inputs resulting directly or indirectly in GHG emissions. Studies on bioethanol (Murphy and McCarthy, 2005) that detail agricultural production, transportation as well as industrial transformation phases conclude that crop production contributes significantly to the greenhouse effect. Beside fuel use for cultivation operations emissions due to fertiliser application should be considered including fertiliser production but also N_2O emissions from soils (this is a controversial issue, for a methodology of measurement see (Brentrup et al., 2000)). Because N_2O is equivalent to 150 times higher than one unit of carbon dioxide this factor may result in emissions of the same order of magnitude as those caused by fuel use (Börjesson, 2009) and eventually compensate any positive effects (Crutzen et al., 2008). Greenhouse gas emissions associated to agricultural production are measured based on explicit assumptions of land use change (LUC). One could mention pioneering works concerning miscanthus in fallow land (Lewandowski et al., 1995) or more recent ones regarding short rotation coppice, miscanthus and rapeseed replacing wheat in arable land, grassland or broadleaved forest (St. Clair et al., 2008), wheat on arable land or grass-covered mineral or peat soil (Börjesson, 2009), wheat monoculture (Scacchi et al., 2010) and rapeseed on set aside land (Malça and Freire, 2010). In some cases energy crop cultivation increases greenhouse gases emissions especially when planted in land previously set aside, thus the benchmark situation may render bioenergy good or bad according to (Börjesson, 2009). As (Malça and Freire, 2010) point out most publications do not consider indirect land use changes (iLUC). Nonetheless, according to several studies (Searchinger et al., 2008; Wicke et al., 2008) indirect land use change induced by increasing bioenergy demand may result in important environmental impacts concerning GHG emissions. Current life cycle assessments of GHG effects fail to take account of indirect LUC (Kløverpris et al., 2008a; Kløverpris et al., 2008b). The present study attempts to follow the guidelines of (Kløverpris et al., 2008b), suggesting that indirect LUC should be analyzed with prospective or consequential LCA taking market mechanisms into account when modeling increased demand of biofuels.

Our approach studies the arable agriculture of Thessaly that provides raw material for the ethanol plant attempting to grasp various substitutions and crop rotations changes triggered by the ethanol plant contracts with farmers. The model is calibrated within national boundaries thus changes due to international trade are beyond its scope. It exploits the optimal solution of the partial equilibrium model subject to agronomic, institutional, market and resource constraints. Therefore the analyst can estimate not only LUC due to ethanol plant operation but also different LUC configurations under alternative policy assumptions. As a matter of fact within the next year policy decisions are going to be made concerning the evolution of the EU CAP beyond 2013, so that different policy variants may result in different GHG emissions for bioethanol. In other words, this analysis aims at demonstrating GHG emission savings due to ethanol are sensitive to policy conditions at a large extent.

This paper is organized in XX sections, including this introduction. Section 2 describes the antecedents of LCAA - classical Activity Analysis adjoined to the environmental Life Cycle Assessment framework and presents the main characteristics of the LCAA approach. Section 3 presents the model specification, then next section discusses estimation assumptions of greenhouse gas emission. The case study is detailed in section 5. Section 6 the optimization results and discussion in section 6 comprises some concluding remarks and ideas for further research.

2. Integrating Activity models and LCA: Life Cycle Activity Analysis

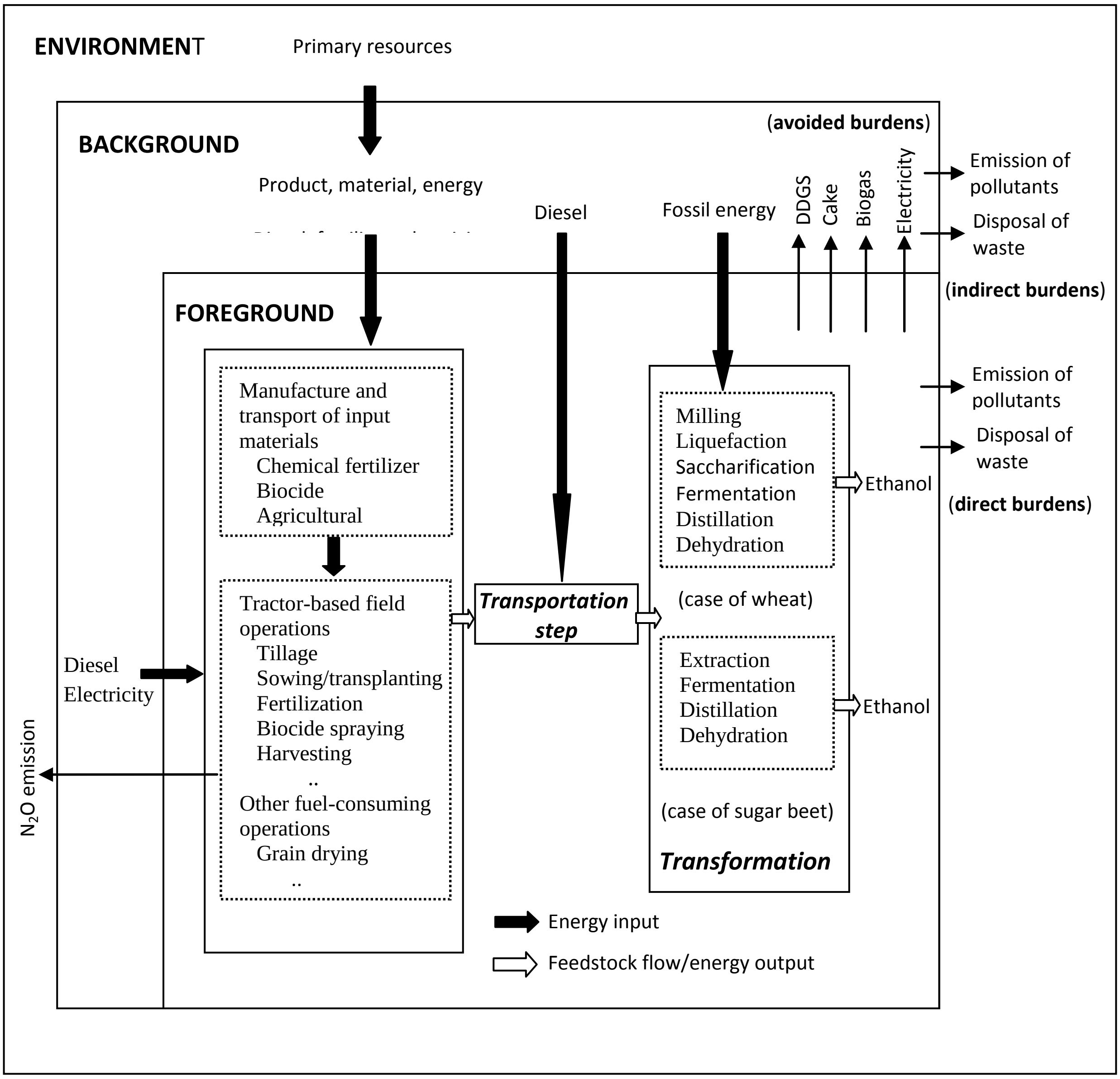
Activity Analysis (AA) was developed by Koopmans in the early fifteens, (Koopmans, 1951, 1957). For this pioneering work, Koopmans received the 1975 Nobel Prize in economics (shared with I. Kantorovich). However, the original formulation was not well suited for numerical solution, since it assumed that there were as many commodities as activities, and that the resulting system of equations had a non-singular solution. A major step was the reformulation of AA as a Linear Programming (LP) problem, permitting any number of activities and any number of commodities (Charnes and Cooper, 1961). In an Activity Analysis model, the possible techniques of production available to a firm, or to the economy as a whole, are given by a finite list of elementary activities that can be used simultaneously and at arbitrary non-negative levels. The resulting production possibility set is a polyhedral cone. The activity analysis model, a generalization of the Leontief input/output model, can be used to generate a large number of distinct linear programs, depending on the objective function to be chosen and on the specific set of factor endowments.

Activity Analysis can be viewed as a tool of partial economic analysis modeling for the representation of an industry or a sector of the economy, providing a mathematical format suitable for the representation of an entire vertical production chain (Thore, 1991). More recently, (Heijungs, 1996, 1997) recognized the conceptual similarities between LCA and classical Activity Analysis (AA) and observed that Life Cycle Inventory is an extension of AA, both being “commodity-by-industry analysis”, generally seen as superior to other forms of inter-industry analysis, (Heijungs, 1996), however no connection between mathematical programming and LCA was made. Thus, a major purpose of LCAA discussed here is to highlight how this connection can be established, using extended mathematical programming formats of AA for an integrated economic and environmental analysis of the life cycle of products.

The classical formulation of AA distinguishes three classes of goods: primary goods (natural resources, materials or labor), intermediate goods (outputs which serve as inputs into subsequent activities) and final goods (outputs). LCAA extends the concept of linear activities to embrace mass and energy fluxes over the entire life cycle of products. In particular, the proposed LCAA model includes one additional category: “environmental goods”, representing primary resources (material or energy drawn directly from the environment) and emissions of pollutants and the disposal of waste (discarded into the environment without subsequent human transformation).

In the LCA terminology, the “environmental goods” are known as environmental burdens and they can be further aggregated into categories of resource usage and environmental impacts, such as global warming, ozone depletion etc. The purpose of such aggregation is two-fold. Firstly, it interprets the environmental burdens included in the output table in terms of environmental problems or hazards. Secondly, by aggregating a large set of data into a smaller number of impact categories it simplifies the decision-making process.

The concepts of "foreground" and "background" proposed within the environmental systems analysis theory are very useful since they help to distinguish between unit processes of direct interest in the study, and other operations with which they exchange materials and energy, (Clift et al., 2000). The foreground may be defined as the endogenous part of the production chain, which includes the set of processes whose selection or mode of operation is affected directly by the decisions of the study. The background denotes the exogenous parts of the production chain, comprising all other processes that interact directly with the foreground system, usually by supplying material or energy to the foreground or receiving material and energy from it. These concepts are illustrated in Figure 1.



Adopting these concepts and terminology, a complete life cycle approach must pursue the production chains both upstream (all the way to their "cradle") and downstream (to their "grave"), by explicitly encompassing the indirect effects associated with the supply of goods together with direct effects of the core system being modeled. Thus, the total environmental impacts are calculated over both the endogenous and the exogenous part of the life cycle. The foreground and background concepts are also useful in setting goals and targets which can be attached to both variables in the foreground and in the background.

3. Modelling of the bio-fuel production system

The integrated micro-economic model represents agricultural supply sector and industrial configuration optimization simultaneously. The model also estimated CO_2 emission and cost of CO_2 saving at optimal.

Model specification

The integrated model combines both agricultural and industry objectives as its objective function represents total surplus that is equal to the sum of industry and agricultural sector surpluses. It is written in GAMS code and uses non-linear solvers. Algebraic notation of model constraints and objective functions along with associated indices, parameters and decision variables are detailed in the appendix I. More detailed description can be found in (Haque et al., 2009).

Model indices: Different crop cultivated by farm is indicated by ‘*j*’. Crops are: soft wheat, hard wheat, irrigated wheat, maize, maize for fodder, tobacco, cotton, dry cotton, sugar beet, tomato, potato, alfalfa and intercropped vetch. Crops having demand curve with negative slope is represented by ‘*k*’. Demand curve for alfalfa assumed to has negative slope in this particular case. Crops need irrigation is indicated by ‘*r*’. Irrigated crops are: tobacco, cotton, maize for fodder, irrigated wheat, potato, sugar beet, tomato, maize, alfalfa. Rotational crops is indicated by ‘rot’. Rotational crops are: maize, maize for fodder, tobacco, sugar beet, cotton, and tomato. Ethanol, DDGS and pulp is indicated by ‘*eth*’, ‘*ddgs*’ and ‘*plp*’, respectively. Agriculture and industry sector is indicated by ‘*agri*’ and ‘*ind*’, respectively.

Parameters

Parameters which are exogenously determined and used in the model are: price of crop *j* (p_j), yield of crop *j* (y_j), subsidy on output of crop *j* (s_j), subsidy on area cultivated by crop *j*(sub_j), variable cost of crop j (v_j), price of ethanol p_{eth}, price of distilled dry grain solubles (DDGS) (p_{ddgs}), price of pulp (p_{plp}), total cultivable land surface of the farm (X), Available irrigated land area of the farm (X_r), rotational coefficient (rot_coeff), decoupling surface (dec_surf), water requirement for crop *j*(wt_j), total water quantity of the region (wt_t), transformation rate from wheat to ethanol (tr_{eth_wir}), transformation rate from sugar beet to ethanol (tr_{eth_sbt}), reference capacity of 35000 tonnes (q_{eth_base}), carbon dioxide emission per ha from crop $j(CO_{2j})$.

Decision variables

Decision variables which values are generated by the model are: area cultivated by crop $j(x_j)$, demand for sugar beet (q_{sbt}), demand for wheat (q_{wir}), quantity of ethanol produced from sugar-beet (q_{eth_sbt}), quantity of ethanol produced from wheat (q_{eth_wir}), total quantity of ethanol produced in a year (q_{eth}),), total quantity of DDGS produced in a year (q_{ddgs}),), total quantity of pulp produced in a year (q_{plp}), annual total cost of the industry (tc_{ind}), carbon dioxide emission in agricultural production (CO_{2agri}), CO_2 emission saving in farming due to introduction of energy crops ($CO_{2save\_farming}$), CO_2 emission in farming for feedstock production (CO_{2eth_agri}), CO_2 emission in transportation of feedstock from farm to plant ($CO_{2transport}$), CO_2 emission in industrial process for ethanol production (CO_{2ind}), CO_2 emission from gasoline to be replaced by ethanol ($CO_{2\ gasoline}$)

Objective function

1. Total economic surplus: total gross margin of farm and profit of the industry:

$$Max\sum_{j=1}^{n}((p_j + s_j)y_j + sub_j - v_j)x_j + \sum_{k=1}^{t}((\alpha - \beta\Sigma w y_k x_k)y_k - v_k)x_k + p_{eth} * q_{eth} + p_{ddgs} * q_{ddgs} + p_{plp} * q_{plp} - tc_{ind} \tag{1}$$

The objective function maximizes total social welfare. The total economic surplus is the sum of surplus (gross margin) generated from agriculture and profit earned by the industry. Gross margin for farm is determined by total revenue earned from selling products and by-product deduced by variable cost. Industrial profit is determined by revenue earned from product and by-product in a year deduced by annualized total cost of the industry.

resource constraints: available land, irrigated land, water for irrigation

policy and quota constraints:

Quotas on cotton, Constraints on alfalfa rotation,

extensification constraints: Rotational vetch cultivation

flexibility constraints:

Maize for fodder area, Potato cultivation area, Tomato cultivation area

Subject to biomass demand and supply constraints:

Balance constraints:

Ethanol quantity equal to ethanol_wheat plus ethanol_sugbeet

Total quantity of DDGS will be equal to the demand of wheat multiplied by transformation rate from wheat to DDGS.

Total quantity of pulp will be equal to the demand of sugar beet multiplied by transformation rate from sugar beet to pulp.

Industry technical constraints:

Total capital cost is derived from expected capacity divided by reference capacity (35 000 t) exponent by scale factor (0.61) and multiplied by reference investment cost (12.4 M Euro) and accumulated other investment cost factor (3.41).

Plant capacity constraint: Annual capacity of ethanol production of the plant (size of the plant) assumed to be between 10000 and 120000 ton.

Constraints and balance relationships related to GHG emissions

4. Estimation of GHG emission in ethanol production system: Methodology

Fossil energy used involved in farm production are calculated on the basis of amount of fuel and fertilizer used in the production process. So, by inputting the amount of fuel used, amount of fertilizer used and the amount of energy used to produce fertilizer, we can calculate the energy input for the production of agricultural biomass. On the other hand, energy used in the industrial processing is calculated on the basis of basic energy used. For example, steam power is used for industrial processing and steam is generated by fuel oil. Thus, amount of fuel oil used for steam generation is considered for steam energy.

Life cycle emission factor is used to calculate CO_2 emission from respective fossil energy used. These conversion factors are enabling to convert activity data into kilograms of carbon dioxide equivalent (CO_2e). Carbon dioxide equivalent is a universal unit of measurement used to indicate the global warming potential of one unit of carbon dioxide. It is used to evaluate the releasing of different greenhouse gases (Malça, 2002), nitrous oxide (N_2O), methane (CH_4) etc. against a common basis (DEFRA, 2010). CO_2 emission factors express the amount of CO_2 in kilograms which is emitted by combusting a certain type of fuel. Life cycle emission factor for a certain fuel consider both direct emission from combustion and indirect emission prior to combustion emitted for extraction, collection, refinement transportation to the consumer of the fuel (DEFRA, 2010). Emission factors can also be based on the energy content, i.e. joules. The emission factors used in this study incorporated emissions from the full life-cycle of the energy and included net CO_2, CH_4 and N_2O emissions. Lifecycle emissions include both direct emissions from combustion and indirect emissions associated with the production and transportation of the fuel (DEFRA, 2010).

Note that GHG depend greatly on how the biomass is cultivated, transported, processed, and converted into fuel or electricity. There is uncertainty in every stages from biomass production to biofuel combustion. A framework for incorporating uncertainty analysis specifically into estimates of the life cycle GHG emissions from the production of biomass can be found in (Johnson et al., 2011).

4.1 GHG emission in agricultural production

Biomass production required ploughing, sowing/transplantation, fertilization, irrigation, harvesting etc. Fossil energy like diesel is required for machinery operation, natural gas, coal, oil is required for fertilizer production. To estimate GHG emission in biomass production, all operational activities and input/material used have been taken into consideration. Main source of emission in the farming is the fuel and fertilizer used in the production process. In the present study, GHG emission in the agriculture sector is calculated on the basis fossil energy used for each crop per ha. CO_2 emission for machinery operation is calculated by the amount of fuel (diesel) used multiplied by emission factor. To calculate emission from fertilizer, the amount of fossil energy used to produce fertilizer is taken into consideration. Natural gas, coal and oil is used for the production of different fertilizer. Fossil energy requirement for fertilizer and their associated CO_2 emission is presented in annex appendix II(Table A-3). Detailed CO_2 emission for cultivation of 1 ha irrigated wheat is presented in appendix II(Table A-4).

Calculation of GHG emission for fertilizer for different crops can be presented with the following matrix notation.

$$GHGq = \begin{pmatrix} 3.116 & 3.45 & 2.83 \end{pmatrix} . \begin{bmatrix} 0.947 & 0.226 & 0.143 \\ 0.0546 & 0.188 & 0.0334 \\ 0.0254 & 0.0306 & 0.0316 \end{bmatrix} . \begin{bmatrix} 123.8 & 206 \\ 20 & 80 \\ 0 & 60 \end{bmatrix}$$

GHGquant(crop) = unitGHGemiss(energy type) energyContent(energy type, element) input(element, crop)

The row vector contains emission factors i.e., kg CO_2 emission per kg fossil energy (natural gas, oil, coal, respectively), 3×3 matrix contains required amount (kg) of fossil energy (natural gas, oil, coal, respectively) for the production of 1 kg respective fertilizer in rows and different fertilizer (N, P_2O_5, K_2O, respectively) in column. The last matrix (3×2) represents requirement of fertilizer (N, P_2O_5, K_2O, respectively) per ha in rows and crops in column. For convenience, two crops, wheat and cotton, respectively are presented here.

We do the same kind of calculations for all crops present in the crop mix of the region under study (Table 3, prepared from appendix II(Table A-3) and Appendix III). The final CO_2 emissions caused by ethanol production at the agricultural stage are the differential between the crop used for biomass (i.e. wheat) and those crops replaced by wheat. For instance, let’s suppose that irrigated wheat is designated to be transformed in bioethanol, cultivated in soil previously cropped by cotton. For each ton of ethanol, 3.344 tons of wheat are required (in other words 3.344 / 7 ha are required to produce 1 t of ethanol), then CO_2 emissions caused by the biomass input to biomass should be (3.344/7)×(614.42 - 1502.15) = - 424.08 kg CO_2 / t ethanol. This is the substitution method that is better implemented when a model is available to estimate all substitutions at the area level, that usually are not obvious at a simple glance.

N_2O emission

N_2O emission from fossil energy used for machinery operation, fertiliser manufacture, etc. and nitrous oxide from the manufacture of nitrogenous fertiliser, is included in the life cycle carbon dioxide equivalent (CO_2e) emission from respective fossil energy used. The present section is devoted to estimate N_2O emission from soil due to use of nitrogenous fertilizer for different crops. Indirect N_2O emission from additions of nitrogenous fertilizer to land due to deposition and leaching is also estimated. (Börjesson, 2009) mentioned that, often emissions of nitrous oxide contribute more than emissions of carbon dioxide, but may vary widely depending on local conditions. Here, emissions of nitrous oxide from land are estimated from the latest IPCC model (IPCC, 2006). According to IPCC model, 1% of nitrogen fertilizer used is directly emitted as N_2O and 1% of direct emission is emitted indirectly. N_2O emission for the cultivation of one ha land is appeared ranges from less than 1 kg per ha to about 4 kg per ha. Highest emission per ha is found in maize production and the lowest is in alfalfa cultivation (Table 2). Global worming potential (GWP) of N_2O is 296 times larger than an equal mass of CO_2 (IPCC, 2006).

Table 1. CO_2 emission for cultivation of 1 ha crops in the area

Sources of CO_2 emission	CO_2 emission per ha cultivation (Kg/ha)										
	sfw	drw	wir	maize	tob	cot	potato	sbt	tom	mzf	alfalfa
Nitrogen	397.4	397.4	397.4	1072.5	578	661.5	528.2	353.2	578	1073.5	177.5
P_2O_5	28.8	28.8	28.8	143.9	115.2	115.2	128.1	57.6	115.2	143.9	259.1
K_2O	0	0	0	0	65	39	113.8	65	65	0	0
Diesel	167.6	167.6	188.3	551.4	815.2	686.5	929.1	393.5	929.1	551.4	280.4
subtotal	**593.7**	**593.7**	**614.4**	**1767.9**	**1573.4**	**1502.1**	**1699.2**	**869.3**	**1687**	**1767.9**	**717**
From N2O	**402.9**	**402.9**	**402.9**	**1087**	**586.1**	**670.7**	**535.6**	**358.2**	**586.1**	**1087**	**180**
Total emission agriculture	**996.6**	**996.6**	**1017**	**2855**	**2160**	**2173**	**2235**	**1228**	**2273**	**2855**	**897**

Table 2. N_2O emission for cultivation of 1 ha crops in the area

Sources of N_2O emission	N_2O emission per ha cultivation (Kg/ha)										
	sfw	drw	wir	maize	tob	cotton	potato	sbt	tomato	mzf	alfalfa
Direct N_2O emissions	1.238	1.238	1.238	3.340	1.800	2.060	1.645	1.100	1.800	3.340	0.553
Indirect N_2O emissions	0.124	0.124	0.124	0.334	0.18	0.206	0.165	0.11	0.18	0.334	0.055
Total N_2O emission	**1.361**	**1.361**	**1.361**	**3.674**	**1.98**	**2.266**	**1.810**	**1.21**	**1.98**	**3.674**	**0.608**
Kg CO_2 equivalent	**402.9**	**402.9**	**402.9**	**1087**	**586.1**	**670.7**	**535.6**	**358.2**	**586.1**	**1087**	**180**

Usually in research work impacts on carbon dioxide emissions from the introduction of energy crops are studied statically and most of the times focus on changes due to conversion of different land uses. During the 1990’s energy crops were allowed to cultivate in obligatory set aside land, thus in several studies the reference system is fallow land.

For instance a study on environmental impact of taking fallow land into use by cultivating Miscathus in Germany is calculated by (Lewandowski et al., 1995). Furthermore, a recent study estimating GHG costs of energy crop production in the UK (St. Clair et al., 2008) focuses mainly on conversion of broadleaved forest or grassland to Short Rotation Coppice or rape seed. Concerning arable land they mention that rapeseed “(OSR) production has similar GHG costs to arable cropping”. Nevertheless when they compare GHG emissions of rapeseed for biodiesel against wheat a concrete even small difference is observed that is multiplied by three in the case of wheat under reduced tillage practice. A similar approach is adopted to assess ethanol GHG benefits where the author compare ethanol produced in Sweden against that produced in Brazil or the US. He concludes that there is good and bad ethanol (Börjesson, 2009). It is stated that grain to ethanol results in no change of CO_2 emissions if it is cultivated on “normal” arable land.

Certainly GHG differentials when converting from grassland to intensive energy cropping are spectacular at the expense of energy crops, however even displacements and replacements among arable crops reveal significant differences in GHG costs or gains. As a matter of fact, in the arable system of Thessaly as the Table 3 below (that is derived from Table 1) shows, GHG differentials for every crop change in pairs. CO_2 emission impacts ranges from -2000 to +2000 kg/ha (when substitute wheat for maize and vice versa). In a mathematical programming context when the marginal land use for energy cropping is determined as the optimal solution of parametric regional farm (income maximisation under constraints) model we apply unitary coefficients in Table 3 in order to calculate post optimal GHG costs or gains of the introduction of energy crops in the crop mix. The aggregate GHG results is converted in an ethanol ton basis in order to calculate the total GHG emissions for bioethanol production and compare them with the alternative gasoline emissions.

It should be noted at this point, that differentials in crop mix without and with the cultivation of the energy crop may be influenced by policy parameters. Especially in Europe changes in the Common Agricultural Policy alter the ‘reference system’ upon which the GHG emissions of the biomass to energy are measured. One can mention a study to estimate supply curves of solid biomass to electricity that points out differences between these curves after the latest 2003 major CAP reform (Lychnaras and Rozakis, 2006).

Table 3. The GHG savings in kg CO_2 equivalent / ha when converting from one crop to the other

GHG changes when converting crop in line to that in column

	sfw	drw	Wir	mze	tob	cot	pot	sbt	tom	mzf	alf
sfw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
drw	0	0	21	1859	1163	1176	1238	231	1277	1859	-100
wir	-21	-21	0	1838	1142	1156	1217	210	1256	1838	-120
mze	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
tob	-1163	-1163	-1142	696	0	13	75	-932	114	696	-1263
cot	-1176	-1176	-1156	683	-13	0	62	-945	100	683	-1276
pot	-1238	-1238	-1217	621	-75	-62	0	-1007	39	621	-1338
sbt	-231	-231	-210	1628	932	945	1007	0	1046	1628	-331
tom	-1277	-1277	-1256	582	-114	-100	-39	-1046	0	582	-1376
mzf	-1859	-1859	-1838	0	-696	-683	-621	-1628	-582	0	-1958
alf	100	100	120	1958	1263	1276	1338	331	1376	1958	0

4.2 CO_2 emission in the industrial process

CO_2 emission during the industrial processing is largely depended on what fuel is used to produced the heat, steam and electricity required for manufacture of bioethanol. In the present study, electricity and steam is used in the industrial processing. Steam is produced by using fuel oil. To produce one ton of steam, 0.072 ton of fuel oil is required. In case of ethanol production from wheat, 5 tons of steam is required for the production of one ton ethanol. Energy input for the transformation process assumed to be the highest part in bioethanol production system. Hence, bio-energy based industrial processing system can drastically improve GHG balance (Koga, 2008). Steam and electricity requirement and CO_2 emission for industrial processing for 1 ton ethanol production from wheat is shown in Table 4.

Table 4. CO_2 emission in the industry for the production of 1 ton ethanol from wheat

Operation/input	Required fossil energy	CO_2 emission
Steam- 5 ton	Fuel oil: 5×0.072 = 0.36 ton	0.36×3450 = 1242 kg
Electricity	503 kWh	503×0.618 = 310.85 kg
Total CO_2 emission		**1552.85 kg**

4.3 GHG saving and cost of CO_2 saving

There are two sectors from where CO_2 emission could be saved. At the first, introduction of energy crop in the farming could reduce emission, provided that energy crop like wheat is less exhaustive compare to some other arable crops. Change in crop mix i.e., indirect land use change (iLUC) could also change GHG emission. Secondly, use of bioethanol that has very limited emission, replaces highly emission gasoline use resulting net emission is reduced.

To estimate GHG saving, life cycle GHG emissions of gasoline are considered as reference for comparison with ethanol. Hence, it is necessary to derive the fuel equivalency ratio between ethanol and gasoline. In terms of fuel efficiency, gasoline is found more fuel efficient but efficiency varies significantly on the types of vehicle engine. (Warnock et al., 2005) mentioned that fuel efficiency of automobiles is reduced by 27 percent on E-85 compare to pure gasoline. On the other hand, (Sheehan et al., 2004) conducted a study with flexible fuel vehicle (FFV) to estimate the efficiency of the engine running on E85 and gasoline and found that the difference is negligible. (Yacobucci, 2005) mentioned that fuel economy of ethanol is reduced by approximately 29. (Macedo et al., 2008) derived and adopted an equivalence of 1 L ethanol (anhydrous) to 0.8 L gasoline. Substitution ratio between ethanol and gasoline is 0.8 has also suggested by (Nguyen et al., 2009). Considering all types of vehicle and findings of above mentioned writers, fuel efficiency of ethanol is considered 80% of gasoline.

Cost of CO_2 saving i.e., the deadweight loss that the society has to pay for CO_2 saving is considered as the cost CO_2 saving. The deadweight loss is derived by the amount of subsidy needed to support the ethanol to be competitive with gasoline deduced by the surplus (if any) gain by the ethanol industry and surplus generated in the agriculture. To estimate the cost of CO_2 emissions saving, net saving is calculated. Net CO_2 savings is the savings from the agriculture due to change in farming practice after introduction of energy crops and the amount of saving due to replacement of fossil fuel by biofuel.

5. Case study for the Thessaly region

To create opportunities for sustainable management of the existing sugar industry infrastructure in Greece under recent reforms in the Common Agricultural Policy, we have stimulated our interest to evaluate possibility of matching the sugar sector with bio-ethanol production. This may help to achieve bio-fuel policy targets and reduce net GHG emission also. In the present study, a micro-economic model of supply chains that includes an agricultural sector model has been developed for this purpose. This latter is supplemented by an industry model of biofuel chains (bioethanol from wheat and sugarbeet), and by the demand scheme for products and by-products model in a way that a partial equilibrium model has been formulated. LC analysis results is integrated so that to form an LCAA model. A micro-economic analysis of biofuel activity is carried out in order to estimate agents' surpluses. The deadweight loss of the activity is calculated against the environmental benefits of reductions in the emissions of greenhouse gases.

5.1. Agricultural Sector

Energy crops for ethanol considered are sugar beet and secondly wheat are cultivated mainly in two types of arable crop farms: sugar-beet producing exploitations and cotton oriented exploitations. Farm Accounting Data Network (FADN) data on number of farms per type, surfaces cultivated, and land set aside concerning the above farm types have been used in this exercise along with detailed data on inputs of arable crops used by each farm.

It is assumed that farms holding sugar-beet quota and possessing considerable experience on its cultivation (since they had multi-year contracts with the sugar industry) will be the first and presumably most efficient suppliers of the ethanol plant with beet. The reason for choosing cotton cultivating farms beside sugar-beet is that an enormous number of farms cultivate this staple crop in the region. In order to ensure profitability for the ethanol plant it is important to spread capital and administrative charges over a longer period. It points out to the attractiveness of using mixed crops, in this case beet and grains, to extend the processing season that can thus count 330 days per year. The cultivation of irrigated wheat is considered to supply ethanol plant by grains, first because output is much higher than that of non-irrigated wheat, soft or hard, and secondly because it means extensive cotton cultivation replacing monoculture with cotton-wheat rotation (Rozakis et al., 2001). CO_2 emission in agricultural sector is calculated by the amount of energy for fuel, fertilizer and chemicals used.

In the present study we use data on farm structure, costs and yields from 2001-2002, i.e., under the CAP is considered (scenario 1) then changes of CAP, i.e., new CAP element like decoupling of aid and cross compliance are introduced in the model (scenario 2). Farms which cultivated at least one stremma (one tenth of a hectare) of cotton or at least one with sugar beet for the farming period 2001-2002 were selected for the study. A group of 344 arable farms out of all farms monitored by the Farm Accountant Data Network (FADN) satisfy the above constraint, representing in total 22,845 farms of the region.

Main crops cultivated by those farms are: Soft wheat, Hard wheat, Irrigated wheat, Maize, Tobacco, Cotton, Dry cotton, Sugar beet, Tomato, Potato, Alfalfa, feedstock maize and intercropped vetch to conform with the cross compliance term of the new CAP. Data used for the particular crop and for each agricultural farm sample were: output (kg/acre), prices (€), subsidy (€/kg and €/acre depending on the type of crop) and the variable costs (€/acre). Variable cost includes: Seeds and seedlings purchased, fertilizers and soil amelioratives, protection chemicals, fuels and lubricants, electrical energy, water, running maintenance of equipment, maintenance of buildings and landed improvements, salaries and social taxes, and wages of hired labour. Life cycle conversion factor is used to calculate CO_2 emission from fossil energy used in farm production.

The agricultural sector model

Partial equilibrium micro-economic models are used to improve representation of the farm sector in agro-industry models and the introduction of energy crops in the crop mix. For instance, (Treguer and Sourie, 2006) have estimated the agricultural surplus generated by the production of energy crops including sugar beet-to-ethanol, and assessed how these new crops can help to maintain farmers' income and farms' structure.

A large number of individual farms are articulated so that to adequately represent regional arable agriculture. Each farm selects a set of activities (cropping plan) in order to maximize gross margin. The farm planning is governed by resource availability, technical and policy constraints. Main constraints are: available land (both total land area and area by land type such as irrigated, non irrigated etc.), irrigation water availability constraints, crop rotational constraints, environmental constraints, and so forth.

5.2. Industry Sector

Technical and economic data for the production process of ethanol and determination of various costs for the industry model are drilled by (Soldatos and Kallivroussis, 2001) adapted to the conditions of ex-sugar factory in Thessaly by (Maki, 2007). Data include a transformation ratio from wheat and sugar beet to ethanol, corresponding prices and required quantities (per produced quantity of ethanol) of additional and auxiliary matters e.g. chemical substances, the requirements in electrical energy and steam and the corresponding costs, production rate of by-products, the sale prices of produced ethanol and by-products, CO_2 emission factor for fossil energy like natural gas and electricity and corresponding quantity of fossil energy required for the industrial process.

Industry sector model

Industrial models for optimisation of bio-energy conversion seek to determine plant size and technology. Detailed information is included on capital and administrative costs (which decrease with plant size), on variable conversion costs (proportional to the output), as well as on transport costs (increasing with plant size). Raw material costs are often assumed proportional to the output and biomass price is perfectly elastic thus constant no matter the quantity demanded by the plant. A typical example of this engineering approach for plant size optimization is a model by (Ngyen and Prince, 1996) on bio-ethanol from sugarcane and sweet sorghum in Australia. Analysis is sufficiently complicated concerning conversion using single or mixed crops and various transport costs, resulting in optimal ranges of size of the conversion plant. With regard to biomass raw material, cane and sweet sorghum prices and yields used are constant, assuming a simplified view that biomass cost increases with higher demand and also that capital costs per unit of output fall in bigger plants.

Profit maximization of the industrial unit determines the optimal size and technical configuration of the plant, giving maximum income from sales of product and by-products and minimal cost of production. The main relationships shaping the feasible area of the industry model deal with capacity, sugar-beet to wheat ratio to ensure maximal duration of operation during the year (330 days), and capital cost linked to size (average capital cost is decreasing for increasing ethanol capacities). Usually size determination is modeled by binary or integer variables, as in a bio-energy application (Mavrotas and Rozakis, 2002) that also mentions a number of studies of the same kind. In this study, since a continuous relationship is available (Soldatos and Kallivroussis, 2001) we preferred to introduce exponential terms (scale coefficients) in the objective function rendering the industrial module non-linear also. Furthermore, feedstock supply i.e., wheat and sugar beet produced in farms, have to satisfy industry needs (raw material demand should be greater than supply). A number of balance constraints concerning by-products, material inputs and environmental indices (such as water for irrigation) complete the constraint structure.

The base capacity of the unit (35000 t EtOH) determines the cost of investment, the cost of equipment, the requirements for the workforce and a line from costs (direct and indirect) that concerned the economic analysis as well as a pattern of the final cost of the first and auxiliary matters, the cost of electrical energy and steam, the cost of maintenance and other costs of operations that concern the production and the administrative support of the unit. A scale coefficient of 0.61 is used in an exponential function linking capital costs to plant capacity. Allowable range of capacities vary from 10000 to 120000 t. Capital costs are shown in Figure 2 illustrating a decreasing rate of increase of capital costs with increasing scale. This means decreasing average capital costs are associated with larger ethanol plants.

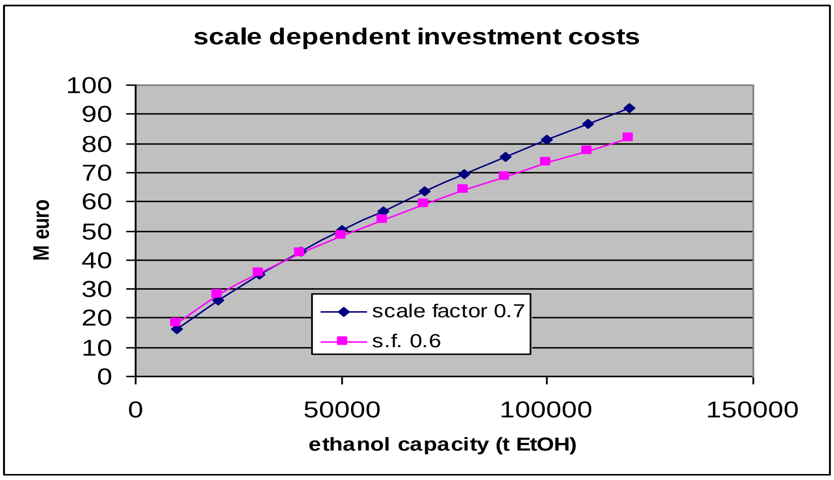


Figure 2. Investment cost of ethanol plant

5. Results and discussion

Parametric optimization of the integrated agro-industrial model determined the optimal crop mix for farmers as well as the best technology configuration for the industry and size of the plant. As expected, biomass costs increase and transformation costs decrease with capacity in any case. Biomass costs are endogenously given by the model (dual prices) resulting from changes in the crop mix to satisfy the increasing biomass demand from the industry. The feedstock (sugar beet and wheat) cost has a positive slope. The model maximizes total profit, thus it proposes the highest possible capacity within the predetermined range of 120000 ton ethanol per year.

Key results of the model concerning the original configuration are presented in figure 3. One can observe that raw material cost is the major part of total cost increasing with plant size. Total average cost is minimized in capacity range of 50 kt ethanol. Explicitly, average capital costs begin at 202 euro/t for small plants (10000 t) and decrease to 77 euro/t for maximal capacity (120000 t). Sugar-beet and wheat amount at almost 40% of total cost for small plants (10000 t)but this element increases to 60% for 120000 t plant.

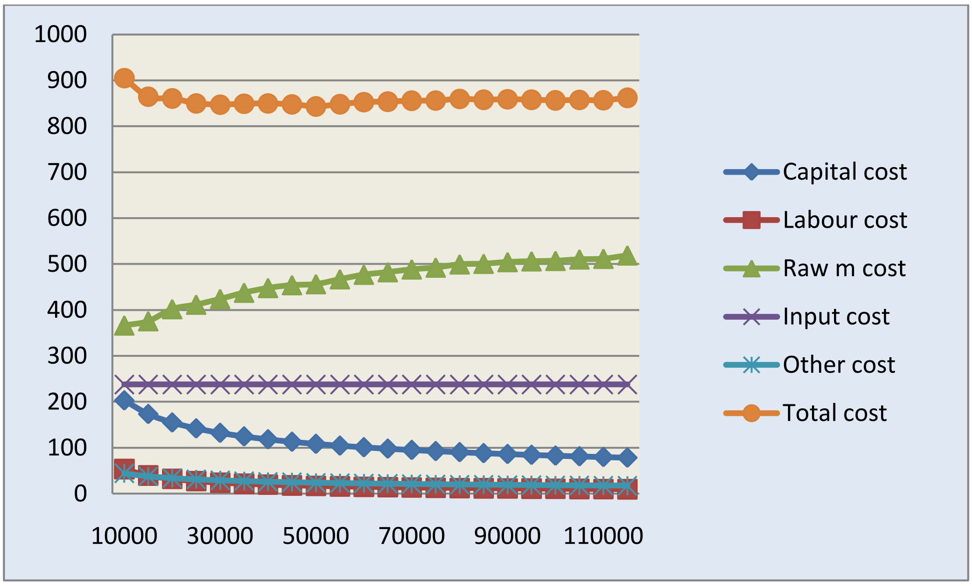


Figure 3 Cost and returns per ton of ethanol production (configuration 1)

Environmental impact of bioethanol production in the sugar industry has been estimated in terms of net change in CO_2eq emission at the atmosphere. There are four stages from where CO_2 emission is considered for bioethanol. First one is at the agricultural sector during feedstock production, secondly during transportation, thirdly during transformation stage in the industry and finally in the combustion stage. Bioethanol combustion is considered GHG neutral but it avoids the quantity emission by equivalent amount gasoline that would be replaced by bioethanol.

The industrial processing stage seems responsible for major part of emission followed by agriculture sector for biomass production and then transportation. CO_2 emission is proportional to plant size i.e., total CO_2 emission is increases as plant size increases.

Different scenarios are considered to estimate GHG performance of bioethanol production system. Firstly the absolute CO_2eq emission considering only direct land use change (LUC) for feedstock production, emission for transportation and for industrial transformation. In the second scenario, GHG emission for indirect land use change (iLUC) is considered. Introduction of energy crop changes crop mix in agriculture that changes GHG emission attributes in agriculture. Taking in to consideration change in crop mix, GHG differentials for without and with the cultivation of energy crop is evaluated within the regional boundary of Thessaly. In the third scenario, along with iLUC in regional boundary of Thessaly, global GHG potential is considered.

Results on GHG emission in different scenarios are presented in Table 5. For the first scenario with direct LUC, total emission in agriculture and transportation is always positive. On the other hand, CO_2 emission saved due to replacement of gasoline by ethanol is presented in negative sign. The total net emission, i.e., considering CO_2 save due to gasoline replaced by bioethanol is appeared in negative sign that expresses net CO_2 saving in ethanol production system. Total net CO_2 saving at optimal solution in different plant size is appeared increasing with the plant size increase but CO_2 emission savings per ton is decreasing. Total net CO_2 saving at optimal plant size of 120kt ethanol plant is 70.6kt and CO_2 saving per ton of ethanol at the optimal is 0.588 ton.

Under the second scenario considering indirect land use change within regional boundary of Thessaly, net CO_2 emission change in agriculture and transportation is estimated by the differences in CO_2 emission with and without ethanol production. One can observe from the Table 5 that the net CO_2 emission in agriculture is negative. This means for the production of ethanol, introduction of energy crops reduces CO_2 emission in the agriculture i.e., CO_2 emission is saved in agriculture. The total net CO_2 emission including emission saved due to replacement of gasoline by ethanol at the optimal plant size of 120kt is appeared 171.9kt that contributed 1.432 ton CO_2 saving per ton of ethanol production.

Under the third scenario considering global indirect land use change, including import and import substitution, GHG potential is more or less similar to the second scenario. Total CO_2 saving at the optimal plant size of 120kt is 172.6kt that contributed 1.438 ton CO_2 saving per ton of ethanol.

Cost of CO_2 saving per ton of ethanol production under the first scenario with direct land use change is appeared high and increasing with increase of plant size (Table 5). At the optimal plant size of 120kt ethanol plant, cost of CO_2 saving is appeared 293.3Euro per ton. On the other hand under the second scenario considering indirect land use change within the regional boundary of Thessaly, cost of CO_2 saving per ton of ethanol production is decreasing with plant size increase. Cost of CO_2 saving at the optimal plant size of 120kt ethanol plant is 120.5 Euro per ton. Under the third scenario considering global indirect land use change and import and import substitution, trend of CO_2 saving cost is unstable within a limited range from 104.2 to 110.8 Euro per ton CO_2eq for different plant size. At the optimal plant size of 120kt ethanol plant, cost of CO_2 saving is appeared 119.9 Euro per ton.

It is evident from the study that in absolute terms, on an average 24% CO_2eq emission for bioethanol production is caused by feedstock production and 75% emission is occurred in industrial processing whereas only 1% is dedicated for transportation. With the optimal plant size of 120kt ethanol per year, 302.6kt CO_2 emission caused by gasoline can be avoided by replacing with ethanol. Thus, significant amount of CO_2 emission can be avoided both in agricultural sector by the introduction of energy crop in crop mix and by the replacement of gasoline with bioethanol but cost of CO_2 saving is appeared to be expensive.

Table 5. GHG emission in the ethanol production system (in kt CO_2eq)

	Under subsidy on cotton @ 55(є/h)							Sub_cot 80 (є/h)
Plant size (kt	60	70	80	90	100	110	120	120
Direct Land Use Change (LUC) considering only wheat and sugar beet production (kt)								
CO_2 emission in agriculture	25.6	30.5	35.6	40.5	45.3	50.3	55.6	55.1
CO_2 in transportation	0.69	0.823	0.967	1.1	1.24	1.38	1.52	1.51
Total CO_2 emission	**26.3**	**31.4**	**36.5**	**41.6**	**46.56**	**51.7**	**57.1**	**56.6**
Indirect LUC (regional boundaries within Thessaly) (kt)								
Net CO_2 emission in agriculture	-20.5	-24.1	-28.2	-33.9	-37.5	-40.9	-45.2	-32.7
Net CO_2 in transportation	0.47	0.56	0.65	0.76	0.86	0.96	1.05	1.2
Total net CO_2 regional_iLUC	**-20.1**	**-23.5**	**-27.5**	**-33.1**	**-36.6**	**-40.0**	**-44.2**	**-31.4**
Indirect LUC import (different crop mix and replaced food crops by imports) (kt)								
Net CO_2 emission in agriculture	22.8	27.9	32.8	37.6	40.3	42.3	47.5	18.2
Net CO_2 in transportation	7.3	8.9	10.5	12.1	12.9	13.5	15.1	5.9
CO_2 avoided_reduc_soya cake_imp	-31.7	-36.9	-42.2	-47.5	-52.8	-58.1	-63.4	-63.4
Total net CO_2 for import_iLUC	**-1.5**	**-0.1**	**1.1**	**2.1**	**0.3**	**-2.3**	**-0.7**	**-39.2**
CO_2 emission at the industrial transformation (kt)								
CO_2 for electricity	15.6	18.2	20.7	23.3	25.9	28.5	31.1	31.1
CO_2 for steam	71.9	83.9	95.8	107.8	119.8	131.8	143.8	143.8
Total CO_2 for industrial processing	**87.4**	**102.0**	**166.6**	**131.2**	**145.7**	**160.3**	**174.9**	**174.9**
CO_2 gasoline to be replace	**-151.3**	**-176.5**	**-201.7**	**-226.9**	**-252.2**	**-277.4**	**-302.6**	**-302.6**
Total net CO_2 emission in different scenarios (kt)								
Total net CO_2 direct LUC (save)	-37.5	-43.1	-48.6	-54.2	-59.8	-65.3	-70.6	-71.1
Total net CO_2 regional_iLUC	-83.9	-98.1	-112.7	-128.9	-143.1	-157.1	-171.9	-159.1
Total net CO_2 include import iLUC	-85.4	-98.1	-111.6	-126.8	-142.7	-159.4	-172.6	-198.4
Total net CO_2 emission per ton of ethanol (t)								
Net CO_2 direct LUC per t ethanol	-0.626	-0.616	-0.607	-0.602	-0.598	-0.594	-0.588	-0.593
Net CO_2 region_iLUC per t ethanol	-1.398	-1.401	-1.409	-1.432	-1.431	-1.428	-1.432	-1.326
Net CO_2 incl.import_iLUC per t eth	-1.424	-1.402	-1.395	-1.409	-1.427	-1.449	-1.438	-1.653
Cost of CO_2 saving								
Total cost of CO_2 saving (million є)	**8.9**	**10.6**	**13.0**	**14.6**	**16.0**	**17.7**	**20.7**	**40.4**
Cost of CO_2 saving direct LUC (є/t)	236.9	246.2	267.6	269.8	267.8	270.3	293.3	567.2
Cost of CO_2 saving_reg_ iLUC(є/t)	106.1	108.3	115.4	113.4	112.0	112.4	120.5	253.6
Cost of CO_2 save.inc.imp iLUC (є/t)	104.2	108.2	116.5	115.3	112.3	110.8	119.9	203.4

6. Conclusions

This paper attempts an economic evaluation of bio-ethanol production in the context of the ex-sugar industry in Thessaly taking into consideration recent changes in the Common Market Organization for sugar in the E.U. and options considered by the Hellenic Sugar Industries as well as to achieve bio-fuel and environmental policy targets.

The work has also demonstrated the potential of a novel tool – Life Cycle Activity Analysis – for an integrated economic and environmental analysis of the material-product chains associated with the life cycle of products. This tool combines the advantages of the Life Cycle Assessment (LCA) methodology, that tracks the environmental consequences of a product, process or service from "cradle" (resource origin) to "grave" (final disposal), with the advantages of using mathematical programming formats of economic Activity Analysis. The methodology allows for the analysis of “What if?” scenario. In this manner, it can be used to *design and evaluate alternative packages of environmental strategy or policy*, including programs of action for recycling and reuse of products, with the aim of identifying more sustainable practices for the future.

An integrated model articulating agricultural supply of biomass with its processing to ethanol maximizing total surplus determines the optimal production level. A plant of 120 kt ethanol represents optimal plant capacity, and is the highest one in the examined range.

Further research should be conducted to take into account uncertainty (Rozakis, 2005). Uncertainty issues concerning not only demand side (ethanol and by-products price volatility) but also supply side (changing policy contexts and competitive crop price volatility) need to be addressed in order to determine ethanol profitability confidence levels. Also additional technical configurations including recent research findings on promising crops such as sorghum (Maki, 2007) could increase farmers’ gains.

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Appendix I

Mathematical specification of the Model

Indices:	j	Crops: {sfw: Soft Wheat, drw: Hard Wheat, wir: Irrigated Wheat, mze: Maize, mzf: Maize for fodder, tob: Tobacco, cot: Cotton, cotd: Dry Cotton, sbt: Sugar Beet, tom: Tomato, pot: Potato, alf: Alfalfa, vik: Intercropped vetch}
	k	Crop(s) having demand curve with negative slope
	r	Irrigated crops: {tob, cot, mzf, wir, pot, sbt, tom, mze, alf, cot}
	rot	Rotational crops: {mze, mzf, tob, sbt, cot, tom}
	$eth,\ ddgs,\ plp$	Ethanol, DDGS: Dried Distillers Grains with Soluble, Pulp
	$agri,\ ind$	Agriculture, industry

Model parameters:

p_j	Price of crop *j*
y_j	Yield of crop j
s_j	Subsidy on output of crop *j*
sub_j	Subsidy on area cultivated by crop *j*
v_j	Variable cost of crop *j*
$P_{\{eth,\ ddgs,\ plp)}$	Price of ethanol, Distilled Dry Grain Solubles (DDGS), pulp
X	Total cultivable land surface of the farm
X_r	Available irrigated land area of the farm
w_f	Weight of farm
rot_coeff	Rotational coefficient
dec_surf	Decoupling surface
wt_j	Water requirement for crop *j*
wt_f	Water capacity of farm
wt_t	Total water quantity of the region
tr_{eth_wir}	Transformation rate from wheat to ethanol
tr_{eth_sbt}	Transformation rate from sugar beet to ethanol
q_{eth_base}	Reference capacity of 35000 tonnes
CO_{2j}	Carbon dioxide emission from crop *j*

Decision variables:

x_j	Area cultivated by crop *j*
$q_{\{sbt,\ wir\}}$	Demand for sugar beet or wheat
$q_{\{eth\_wir,\ eth\_sbt\}}$	Quantity of ethanol produced from wheat or sugar-beet
$q_{\{eth,\ ddgs,\ plp\}}$	Total quantity of ethanol, DDGS or pulp produced in a year
tc_{ind}	Annual total cost of the industry
CO_{2agri}	Carbon dioxide emission in agricultural production
$CO_{2save\_farming}$	CO_2 emission saving in farming due to introduction of energy crops
CO_{2eth_agri}	CO_2 emission in farming for feedstock production
$CO_{2transport}$	CO_2 emission in transportation of feedstock from farm to plant
CO_{2ind}	CO_2 emission in industrial process for ethanol production
$CO_{2\ gasoline}$	CO_2 emission from gasoline to be replaced by ethanol

Appendix II. Estimation of CO_2 emission factor for diesel

The process steps of the diesel fuel chain are:

- (a) exploration, extraction, preparation and transportation of crude oil to the refinery;
- (b) diesel fuel production in the refinery;
- (c) transportation of the diesel fuel to the consumer;
- (d) losses due to evaporation and during transfer processes; and
- (e) combustion of diesel fuel.

At a density of 0.835 kg/l of diesel fuel and a lower heating value (LHV) of 42.7 MJ/kg (respectively, 37 MJ/l) of diesel fuel, total CO_2 emissions (direct and indirect) are 3.45 kg CO_2/kg (respectively, 2.88 kg CO_2/l) diesel fuel (Lewandowski et al., 1995) (Table 1).

Table A-1. Emission factors expressed in kg CO_2/kg diesel fuel

Indirect emissions	
Exploration and transportation of crude oil to the refinery	0.06
Refinery conversion	0.16-0.26
Transportation to consumer	0.02
Evaporation	<0.005
Sum indirect emissions	0.25-0.35
Direct emissions	3.15
Total emissions	**3.4-3.49**

4.1.2 Estimation of CO_2 emission factor for hard coal

Approximately 4.5% of its energy content is needed for the exploration, mining and transportation of hard coal. The LHV of hard coal is 29.3 MJ/kg; 1.32 MJ are needed to obtain 1 kg hard coal. This energy is provided mainly by diesel fuel. For 1 kg hard coal, 0.0309 kg diesel fuel with an energy content of 42.7 MJ/kg is needed. The amount of diesel fuel consumed is multiplied by its CO_2-emission factor. The result shows that, 0.0309 kg diesel fuel/kg hard coal x 3.45 kg CO_2/kg diesel fuel = 0.1 kg CO_2 are emitted for the provision of 1 kg hard coal. Direct CO_2emissions during the combustion of hard coal are 93.2 kg CO_2/GJ or 2.73 kg CO_2/ kg hard coal. Thus the CO_2 emission factor for hard coal is 2.83 kg CO_2/kg hard coal (direct and indirect).

4.1.3 CO_2 emission factor for electrical energy

The CO_2 emission factor for electrical energy is calculated 0.618 kg CO_2/kWh (Table 2). This figure is calculated on the basis of the provisional chain for the primary energy which is consumed during the production of electricity, as well as power station losses during electricity production.

4.1.4 CO_2 emission factor for natural gas and gasoline

Life cycle emission factor for natural gas is 3.116 kg CO_2/kg natural gas on the other hand life cycle emission factor for gasoline is estimated 3.152 kg CO_2/kg gasoline (DEFRA, 2010) (Table 2). (DEFRA, 2010) calculated those emission factors considering both direct emission at use stage and indirect emission emitted prior to the use.

Table A-2. Energy content and CO_2 emission factors for different kinds of energy or fuel

Kind of fuel or energy	(MJ/kg, MJ/kWh)	CO_2 emission factor
Diesel fuel, fuel oil	42.7 MJ/kg	3.45 kg CO_2/kg[a]
Hard coal	29.3 MJ/kg	2.83 kg CO_2/kg[a]
Electricity	3.6 MJ/kWh	0.618 kg CO_2/kWh[a]
Natural gas		3.116 kg CO_2/kg[b]
Gasoline	43.5MJ/Kg	3.152 kg CO_2/kg[b]

[a] (Lewandowski et al., 1995)

[b] (DEFRA, 2010)

Table A-3. Fossil energy requirement and CO_2 emission per kg fertilizer

Fossil energy for fertilizer production	N	P_2O_5	K_2O
Nat gas	2.951 (0.947)	0.704 (0.226)	0.446 (0.143)
Oil	0.188 (0.0546)	0.649 (0.188)	0.115 (0.0334)
Coal	0.072 (0.0254)	0.087 (0.0306)	0.089 (0.0316)
Total emission	**3.211**	**1.44**	**0.65**

Parenthesis represent amount of input to produce one kg of respective fertilizer (Malça, 2002).

Table A-4. CO_2 emission for cultivation of 1 ha irrigated wheat.

Operation/input	Required fossil energy	CO_2 emission
Machinery operation like plowing, sowing/ transplanting, fertilization, irrigation, harvesting, etc.	Diesel: 54.57 litre	54.57×3.45[a]=188.27 kg
Fertilizer Nitrogen- 123.75 kg	Natural gas:123.75×0.947[b] =117.69kg Oil: 123.75×0.0546[b] = 6.75 kg Coil: 123.75×0.0254[b] = 3.14 kg	117.19×3.116[a]=365.17 kg 6.76×3.45[a] = 23.31 kg 3.09×2.83[a] = 8.9 kg
	Total CO_2 for Nitrogen	397.38 kg
P_2O_5-20 kg	Natural gas: 20×0.226[b] = 4.52kg Oil: 20×0.188[b] = 3.76 kg Coil: 20×0.0306[b] = 0.61kg	4.52×3.116[a] =14.08 kg 3.76×3.45[a] = 12.97 kg 0.61×2.83[a] = 1.73 kg
	Total CO_2 for P_2O_5	28.78 kg
Total CO_2 emission in wheat production (per ha)		614.42 kg

[a] Emission factor from Table 4.2.

[b] required amount (kg) of input to produce 1 kg respective fertilizer from Table 3.

Appendix III: fossil input requirement for crop cultivation

Item	Crops										
	s.wheat	d.wheat	r.wheat	maize	tobacco	cotton	potato	s.beet	tomato	Maize(f)	alfalfa
Diesel (lit./ha)	48.57	48.57	54.57	159.8	236.3	199	269.3	114.1	269.3	159.84	81.27
Fertilizer											
N (kg/ha)	123.8	123.8	123.8	334	180	206	164.5	110	180	334	55.28
P_2O_5 (kg/ha)	20	20	20	100	80	80	89	40	80	100	180
K_2O (kg/ha)	0	0	0	0	100	60	175	100	100	0	0