TOWARDS SUSTAINABLE AGRI-FOOD SYSTEMS:
BALANCING BETWEEN MARKETS AND SOCIETY

Achieving GHG emission commitments and food security objectives in Norwegian agriculture

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1. Introduction

At the UN climate change conference in Paris in November 2015, Norway committed itself to a 40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 levels. Agriculture accounts for 8% of Norway's total GHG emissions. If GHGs from drained and cultivated wetland (categorized under land use, land use change and forestry) are included, the share is 13%; this for a sector that accounts for roughly 0.3% of GDP. As is the case in most countries, agriculture is currently exempt from emission reduction measures, including the European Union's Emissions Trading System (ETS), in which Norway participates. But the country has recently signaled its intention to include agriculture in future emission reduction efforts. Consideration is being given to how best to achieve GHG reductions in the sector.

A recent report by the Norwegian Green Tax Commission, established by the government to evaluate policy options for achieving emission reductions, (Government of Norway, 2015) emphasizes the importance of including agriculture. The Commission suggests that agricultural emissions should be taxed at the same rate as for other sectors. It also recommends that reductions in the production and consumption of red meat should be specifically targeted, through cuts in production grants to farmers and the imposition of consumption taxes. Unsurprisingly, this proposed policy shift is extremely controversial and faces resistance, particularly from the farmers' unions. Farmers argue that the maintenance of domestic agricultural production is crucial for achieving national food security objectives, in addition to pursuing other aims such as the maintenance of economic activity in rural areas and landscape preservation. Food security, which has been a key policy objective since the end of the Second World War, has been interpreted in Norway as requiring high levels of self-sufficiency in basic agricultural commodities. To achieve this, substantial subsidies are provided to farmers and domestic prices of many commodities are kept at high levels by restricting imports. The Organization for Economic Cooperation and Development (OECD) estimates that the total financial support provided to Norwegian agriculture in 2015 was equivalent to 62% of the value of gross farm receipts, which made Norway (along with Switzerland) a leader in the amount of support provided to agriculture by the 50 OECD member and non-member countries monitored by the Organization (OECD, 2016). In this paper we analyze policy options for achieving a 40% reduction in agricultural GHG emissions, consistent with the economy-wide target, while imposing the restriction that national food production measured in calories should be maintained (the food security target). This is consistent with the way that the Norwegian government identifies the country's food security objective.

In section 2 we outline the current situation with respect to GHG emissions in Norwegian agriculture. In section 3 we illustrate the policy issues involved by considering two product aggregates that are intensive in the use of land for crop production (grainland) and grassland, respectively. The aggregates are based on data for the main commodities in Norwegian agriculture relating to GHG emissions, land use, caloric content, subsidies, and costs per unit of production. We show that even though the opportunity set (*i.e.*, the production combinations that are possible within technical constraints) is narrow, a 40% cut in emissions is achievable by substituting from ruminant products that are intensive in the use of grassland to products based on grainland. We also show that the emissions reduction both reduces government budgetary costs and land use, i.e., ruminant products are characterized by relatively high subsidies and land use.

Two-dimensional analysis ignores the fact that per unit emissions from dairy production are low compared to other ruminant products (*i.e.*, beef and sheep production). Both in terms of production value and agricultural employment, dairy farming is the most important component of Norwegian agriculture. Consequently, milk production deserves to be separated from ruminant meat production. Finally in section 4, we present a detailed analysis of policy options derived from a disaggregated model that includes all the major products in Norwegian agriculture. In the model-based analysis, we examine first the imposition of a carbon tax, while maintaining existing agricultural support policies and import protection, and achieving the food security (production of calories) target. Since the imposition of a carbon tax in agriculture presents both technical and political challenges, we then examine an alternative approach of changing the existing structure of agricultural support to approximate the same result. We show that it is possible to change current subsidy rates to mimic the carbon tax and calorie target solution. The explanation for this is that ruminant products not only generate high emissions per produced calorie, but they are also the most highly subsidized products. Meat from ruminants is relatively unimportant in achieving Norway's food security objective of calorie availability.

2. GHG emissions in Norwegian agriculture

GHG emissions from various sources in Norwegian agriculture (2011), as notified in the Norwegian national inventory to the Intergovernmental Panel on Climate Change (IPCC), are shown in Figure 1. The green columns are emissions under Chapter 4 'Agriculture' included in the Kyoto protocol, while the black columns are emissions under Chapter 5 'Land use, land-use change and forestry'. For agriculture, these include emissions from cultivated soil. It can be seen that methane from enteric fermentation (associated with ruminants) and carbon dioxide from cultivated organic soil (drained peatland) are by far the largest sources of GHG emissions from agriculture. Each accounts for about a quarter of the total.

[**Figure 1**]

Between 85 and 150 thousand hectares of peatland are used in Norwegian agriculture (Maljanen *et al*., 2010). Grønlund *et al*. (2008) estimate that the carbon loss from cultivated organic soils amounts to 1.8–2 million tons of CO_2 eq. per year due to peat degradation. This is roughly 3–4% of total anthropogenic GHG emissions in Norway. The restoration of peatland (its removal from agricultural production and reconversion to wetland) could potentially make an important contribution to reducing agricultural emissions. However, in this paper we do not consider that option and instead focus on emissions under Chapter 4 in the Kyoto protocol (the green columns in Figure 1).

Estimates of emissions per kilogram for the main products of Norwegian agriculture (carbon loss from organic soil cultivation not included) are given in the last column of Table 3. These estimates are based on a recent Norwegian report (Grønlund and Harstad, 2014). As international studies generally show (*e.g.*, Ripple *et al.*, 2014), emissions per kilogram are highest for ruminants, they are in the middle range for white meat and milk, and are lowest for vegetable products.

Some studies in Europe (*e.g.*, MacLeod *et al*., 2010) have shown that there is potential for GHG reduction through changes in farming practices, and that some climate-friendly technological options can be cost-saving. In other words, farmers could actually improve profitability if they were to adopt these technologies. But in the case of Norway, currently available options for changes in farm practices (e.g. fertilizer management; manure management; composition of fodder) have been estimated to have only marginal impacts on agricultural emissions (KLIF, 2010). Consequently, in this paper we focus on other options for reducing emissions in Norway, namely changes in the composition of agricultural output and, in particular, a reduction in ruminant meat production.

3. The basic framework

The amount of land that is suitable for farming in Norway restricts the opportunity set in agricultural production. Farmland is scarce in Norway, in particular, land suitable for grain production. To illustrate the tradeoffs between GHG emission reductions and national food production on scarce farmland, we consider two product aggregates that are intensive in the use of grainland (G) and grassland (R), respectively The G aggregate is composed of vegetables (mainly food grain) and products from monogastric animals (*i.e.*, pigs and poultry), while R includes products from ruminants *(i.e.*, milk, beef, and sheep). Table 1 shows output, use of land, GHG emissions, and economic indicators per 1,000 kcal produced by these aggregates. The aggregates are constructed from the product-specific numbers for the main commodities in Norwegian agriculture.

[**Table 1**]

G products can only be produced on grainland (*i.e.*, land suitable for grain production), while R products can be provided on all farmland (*i.e.*, grass can also be produced on grainland). Note from Table 1 that R products also require some grainland to provide the concentrates that supplement roughage in the diet of animals.

In figures 1 and 2, production of the two products, denoted by Y_G and Y_R, are measured in 1,000 kcal along the vertical and horizontal axes, respectively. The upper boundary of the opportunity set is defined by the two green lines that represent restrictions with respect to available grainland (light green) and total farmland (dark green). The grainland restriction (light green) is:

(1) $$\pi_G Y_G + \pi_R Y_R \leq \bar{L}_G \ ,$$

where π_G is the amount of grainland required to produce 1,000 kcal of Y_G while π_R is the amount of grainland required to supply the necessary amount of grain to feed ruminants and to provide 1,000 kcal of Y_R. $\bar{L}_G$ is the available grainland (55% of total farmland). When it comes to total use of farmland (dark green line in the figures), grassland is included. λ_R is the amount of grassland required to produce 1,000 kcal Y_R, while $\bar{L}$ is total available farmland (about 1 million ha). The total land restriction is:

(2) $$\pi_G Y_G + (\pi_R + \lambda_R) Y_R \leq \bar{L}.$$

The numerical values for the coefficients π_G, π_R and λ_R are those in the second and third columns of Table 1.

The slope of the two land restrictions can be interpreted as opportunity costs, *e.g.*, loss of G production when R production is increased by one unit and *vice versa*. For small levels of R, *i.e.*, on the less steep light green line the opportunity cost is relatively low since R mainly uses abundant grassland. For high levels of R, the steeper dark green line applies. R production depresses G to a large extent since grass production in that interval also takes place on grainland.

We now assume that Norway imposes a restriction on GHG emissions to meet its obligations under the UN climate agreement. This restriction is formulated as:

(3) $$\varepsilon_G Y_G + \varepsilon_R Y_R \ \leq \propto \bar{E} \ .$$

$\bar{E}$ is the emission in the base year (roughly 4.3 million tons of CO_2 equivalent) and α is the downscale factor (α = 0.6, *i.e.*, a 40% reduction). $\varepsilon_j \ (j = G, R)$ denotes the emission coefficients from column 4 in Table 1. The emission curve is coloured black in the figures. In Figure 1 it shows base year emissions, while in Figure 2 it serves as a ceiling on emissions with the reduction commitment.

In our policy analysis we also assume that national production of agricultural commodities (measured in calories) should, at a minimum, be kept at the current level, formulated as:

(4) $$Y_T + Y_G \geq \ \beta \bar{F}.$$

Here, $\bar{F}$, denotes calories produced for domestic consumption in the base year (about 2,100 billion kcal) and β = 1. The calorie requirement is represented by the straight red line in the figures that by definition is at 45° to the axes. In the policy analysis illustrated in Figure 2 it serves as a lower bound restriction on energy production.

It is also important to keep track of production costs in the solutions. The total cost of producing agricultural products, TC, is:

(5) $$\gamma_T Y_T + \gamma_G Y_G = TC ,$$

where γ_j (j = G, R) is the unit cost for the two aggregates in the fifth column in Table 1. Isocost curves are coloured blue in figures 1 and 2. The costs are, as in the producer support estimate (PSE) computed by the OECD, based on unit producer prices (market prices plus subsidies), so the blue line can also be interpreted as a producer isovalue revenue line.

In Figure 1 the current situation (base solution) is denoted by the point 0 where the lines for GHG emissions, calorie production, and costs intersect. It can be seen that this point is at the steep part (dark green) of the land restriction, *i.e.*, all available land is employed but a substantial part of the grainland is used for grass production. Also, note that the GHG line and cost line are steeply sloped compared to the 45° calorie line, *i.e.*, per calorie produced R results in both substantially higher emissions and costs compared to G.

[**Figure 1**]

When we impose the ceiling on emissions (α = 0.6) and the floor on calorie production (β = 1), the opportunity set narrows substantially to the cross-hatched area in Figure 2. Both the ceiling on emissions and the floor on calorie production are binding, but land is now idle. To meet the policy objectives, G production has replaced R production. Note, also that the blue cost line has shifted south west (a 20% reduction in costs); *i.e.*, it is possible to maintain the current production of calories from Norwegian agriculture while reducing emissions and production costs substantially, by 40 % and 20 %, respectively

[**Figure 2**]

4. Disaggregated model analysis

While the main mechanisms for achieving emissions reductions under policy constraints are illustrated in the figures, a more disaggregated model is required to quantify impacts on production, composition of consumption, land use, agricultural support, and economic welfare. In particular, it is important to separate milk production from the production of ruminant meat and grain (which would require a three dimensional figure graphically). It is evident from Table 2 that dairy production scores well on GHG emissions and use of resources per unit of produced calories compared to ruminant meat. Therefore, in the following analysis we use a model that includes separate sectors for the products that make up the G and R aggregates. The disaggregated sectors and main coefficients per kilo produced are given in Table 3.

[**Table 2**]

[**Table 3**]

4.1 The model and data

The model that we use maximises the sum of producers' and consumers' surplus (inclusive of exogenous subsidy rates and import tariffs). Domestic demand is represented by linear functions calibrated to price and consumption levels in the base year 2011, measured at the farm level. Because of the closed economy characteristics of Norwegian agriculture (high tariffs and restrictive tariff-rate quotas limit the imports of major commodities), the consumption of most products is equal to production reported in the first column of Table 4.[1]

Constant returns to scale, *i.e.*, a Leontief-type production function, is assumed with respect to domestic production for each of the main commodities in Norwegian agriculture, based on the coefficients reported in Table 3. Import supply is represented by given world market prices inclusive of import tariffs, or as determined by tariff-rate quotas.

Restrictions with respect to available food grain land, grain land, and total land are imposed. Total infield agricultural land is 1 million hectares (3% of total land area). Of that total 55% is suitable for grain production, while only 27% can provide food grain. The residual is only suitable for growing grass to support ruminants.[2]

The model allows for restrictions with respect to GHG emissions from production and/or consumption (ceilings); domestic consumption and/or production of calories and proteins; calories and proteins imported in the form of feed (floors). Shadow prices associated with restrictions are interpreted as subsidies or taxes necessary to satisfy the restrictions.
Economic welfare is defined as the sum of the producers' and consumers' surplus minus exogenous subsidies and tariff revenues.

4.2. Analysis and results

The model solution for the current situation in Norwegian agriculture, given in the first column in Table 4. Departing from that simulation, *i.e.*, maintaining existing agricultural support policies and prohibitive trade protection, we introduce a carbon tax of NOK 1,453 per ton CO2 equivalent (roughly €160) and a calorie subsidy of NOK 0.61 per 1,000 Kcal (roughly €0.068) in order to achieve the 40% emission reduction ($\alpha = 0.6$) while maintaining current energy production ($\beta = 1$). The assumption of constant returns to scale implies that the carbon tax and calorie subsidy will be shifted to consumers through market prices.

As might be expected from the discussion in section 3, column 2 in Table 4 shows that the net carbon tax (carbon tax adjusted for calorie subsidy) primarily affects ruminant meat production. Sheepmeat and beef production are reduced by 85% and 61%, respectively. Since prohibitive tariffs prevent imports, consumption is reduced accordingly. Substantially smaller impacts are observed for other animal products (4-11% reductions). Note that cow milk (and beef from culled dairy cows) is reduced by only 7%, reflecting that dairying is different from ruminant meat production when it comes to emissions. To counterbalance the reduction in the supply of calories from animals, production of food grain increases by 44%.

[**Table 4**]

[1] The main exception is consumption of food grain that incorporates about 50% of imports. Imports of other products are low. All imports are within tariff rate quotas, i.e., there are no imports under the most favored nation tariff rates bound in WTO. Consequently, the first column in Table 4 can be interpreted as the residual demand for Norwegian products.

[2] The products included in the model occupy 94% of available farmland, *i.e.*, we apply 0.94 ha as a ceiling on total agricultural land in the simulations. Although 27% of the total farmland is categorized as food grain quality, only 5% is currently used for food grain production. The main explanation is the low quality of Norwegian wheat due to the relatively cold and wet growing season. In the model simulations, the ceiling on food grain land is set to 10% of total available farmland. The ceiling on total grain land (inclusive feed grain) is set to 44% of total available farmland (i.e., a 20% reduction factor is used to allow for crop rotation).

The use of both grainland and grassland declines[3] in the simulation (30% and 50% reductions, respectively) so that only 62% of the total available land is employed. With reference to Figure 2, we move north-west (from the base solution marked 0 in Figure 1) along the binding lower level on energy production (red line), in particular by replacing ruminant meat with vegetable food, until the GHG target (black line) is met at point 1. Since land is idle at this point, the land restrictions (green lines) are not binding. Note also that this movement causes a 33% reduction in agricultural support, i.e., the cost line (blue line) shifts inwards.

The reason why it is possible to reach the combined GHG and calorie targets with substantially less land use and lower agricultural support is that both emissions and the use of resources per unit of supplied energy are substantially higher for ruminant meat than for all other products.

As indicated earlier, a carbon tax may be difficult to apply in agriculture for both technical and political reasons. It can be difficult technically to tax emissions at source in agriculture, due to the non-point source character of many of these. In addition, the general view, fueled by the farm lobby, is that food production should not be subject to a carbon tax. The high level of the tax that results from the simulation, *i.e.*, close to NOK 1,500 per ton of CO2 equivalent or around €160-€170 at recent exchange rates, would certainly strengthen the opposition. As indicated earlier, Norway participates in the European Union’s Emissions Trading System and the size of the taxes required are far higher than the ETS emission price that has recently confronted other sectors in the economy (roughly €5 per ton of CO2). For the general public it might appear as if agriculture would be taxed more highly than other sectors, which could be in conflict with principles for an efficient economy-wide emission reduction through the application of a uniform carbon tax.

But this argument ignores the fact that Norwegian agriculture is highly subsidized, and, this is particularly so for the high-emitting ruminant meat components. Given this, an alternative to the imposition of a carbon tax would be to change the structure of support to achieve a reduction in production and a consequent reduction in emissions. If we translate the combined carbon tax/calorie subsidy rates into a net carbon tax per kilo produced, we obtain the rates in column 1 of Table 5. We see that the net tax is low for most products, except for ruminant meat. Relative to the market price at the farm level, the net tax is 12-14% for cow milk, eggs, pigmeat and poultry, while the net carbon tax for food grain is negative. For beef and sheep meat, characterized by very high emissions per produced unit of calories, the net tax is 67% and 94%, respectively.

[**Table 5**]

The third column shows that the current subsidies provided to ruminant meat are far higher than the net carbon tax, *i.e.*, the subsidy level for these products would still be relatively high after the deduction of the net carbon tax (as shown in the last column). This would also be the case for milk. For products like pigmeat, eggs and potatoes the net carbon tax slightly exceeds current subsides, not because these products cause high emissions but because they receive less in direct subsidies (they are mostly supported by higher prices through import barriers). Food grain would have an increased subsidy level; *i.e.*, the calorie subsidy exceeds the carbon tax for this product.

6. Concluding remarks

We have demonstrated that it is possible to achieve a 40% reduction in agricultural GHG emissions, in line with Norway’s economy-wide commitment at the UN climate change

[3] Although food grain production has increased, this is more than offset by lower production of feed grains due to reduced demand for meat.

conference in Paris in 2015, while maintaining Norway's food security objective expressed in terms of calories derived from national food production.

These joint objectives can be accomplished by reducing the production and consumption of ruminant meat, which generates substantially higher emissions and use of resources per calorie produced than all other products, and by increasing the production of calories from vegetable products (like food grain). Only small changes in other agricultural sectors, like dairy farming, pigs and poultry, would be required.

A common objection to the application of the polluter pays principle with respect to agricultural GHG emissions is that it can be inefficient and imprecise since it is difficult to measure and target directly the source of emissions (*e.g.*, exhalation of methane from animals; carbon losses from soil; emissions from manure management etc.). Actual emissions depend on the practices of individual farmers, and there may be substantial uncertainty with respect to emission levels associated with different activities.

A second best approach is to link corrective taxes to observable commodities or production factors that exhibit a high correlation to emissions, *e.g.*, per head of various animal species, production levels, use of synthetic nitrogen, other agricultural practices, and regional differences. The International Panel on Climate Change (IPCC)'s manual for national inventories with respect to GHG emissions from agriculture, used to monitor fulfilment of commitments, adopts this method and credits for emission reductions in current UN climate agreements are based on such principles.

A potential efficiency problem in linking payments to indirect emissions indicators is that an individual farmer will have limited incentives to reduce farm or site specific emissions; *e.g.*, related to manure management, use of fertilizer, composition of fodder, soil, and tillage. But in the case of Norway, available options for changes in farming practices have been estimated to have only marginal impacts on total agricultural emissions (KLIF, 2010). Over the longer term, technological progress may open up the possibility for reducing emissions per unit of agricultural output (in the Norwegian case innovations relating to emissions from ruminants), but dietary changes will also be necessary (see *e.g.*, Bryngelsson et al., 2016). In the closed-economy context of Norwegian agriculture changes in the composition of agricultural output and resulting changes in consumption, as analysed in this paper, seem to be required to achieve a substantial reduction in emissions.

For both technical reasons and political reasons carbon taxes on food production may be hard to introduce. Since there is a high positive correlation between GHG emissions and subsidy levels in Norwegian agriculture, an indirect approach would be to reduce subsidies to ruminant meat production, and increase subsidies to grain and vegetable production. By changing the structure of support it would be possible to mimic the carbon tax solution.

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Table 1. Output and use of resources per 1,000 kcal for products intensive in the use of grassland and grainland

Products intensive in: (per 1,000 kcal)	*Production (kg)*	*Land use grass (10^{-3} ha)*	*Land use grain (10^{-3} ha)*	*GHG (kg CO2 equiv.)*	*Costs (NOK)*	*Budget support (NOK)*
Grassland (R)	1.391	0.518	0.1629	3.006	17.392	7.508
Grainland (G)	0.710	0	0.2398	0.858	9.933	0.825

Source: Calculations made by the authors using the database for the sector model of Norwegian agriculture (Jordmod).

Table 2. Output and use of resources per 1,000 kcal for products intensive in the use of grassland and grainland with dairy separated from other ruminants

Products intensive in: (per 1,000 kcal)	*Production (kg)*	*Land use grass (10^{-3} ha)*	*Land use grain (10^{-3} ha)*	*GHG (kg CO2 equiv.)*	*Costs (NOK)*	*Budget support (NOK)*
Grassland (R)						
Dairy	1.46	0.255	0.115	1.46	11.31	3.73
Ruminant meat	0.77	3.025	0.616	17.80	75.40	43.57
Grainland (G)	0.71	0	2.398	0.86	9.93	0.83

Source: Calculations made by the authors using the database for the sector model of Norwegian agriculture (Jordmod),

Table 3. Disaggregated sectors - coefficients per kilo produced

Product	*Land use (10^{-3} ha)[1]*	*Roug-hage (feed units)*	*Feed grain (kg)*	*Budget support (NOK)*	*Market price support (NOK)*	*Costs (NOK)*	*Kcal[2]*	*GHG (Kg CO[2])*
Milk (incl.13.8g beef[1])	0.255	0.61	0.27	2.56	1.87	7.77	687	1.00
Ruminants other								
Beef from fed calves	3.032	8.15	2.33	23.26	21.24	65.26	1230	20.00
Beef, extensive	5.086	13.42	4.19	61.85	21.24	103.85	1230	26.00
Sheepmeat	7.342	23.28	2.22	109.72	2.78	148.89	1456	26.00
Grain based products								
Pigmeat	0.790		2.69	1.79	12.83	26.24	1628	2.65
Poultrymeat	0.460		1.56	2.98	25.86	36.09	1150	2.00
Eggs	0.585		1.99	0.69	15.43	22.09	1250	2.00
Food grains	0.256			1.36	0.84	3.79	2570	0.50
Feed grains	0.294			1.56	0.83	3.76	3020	0.50
Potatoes	0.060			0.18	3.36	5.33	590	0.50

Notes: [1] Production of beef from culled dairy cattle; [2] Per kg of edible product.

Source: Calculations made by the authors using the database for the sector model of Norwegian agriculture (Jordmod).

Table 4. Model results – current situation compared to a policy change to achieve a 40% reduction in GHG emissions (α = 0.6) while maintaining calorie production (β = 1)

	Base solution	**Policy change α = 0.60; β = 1**	**% of base solution**
Production (mill kg)			
Cow milk	1,508	1,403	93 %
Beef	82	32	39 %
Culled milk cows	21	19	93 %
Fed dairy calves	42	13	31 %
Extensive	19	0	0 %
Goat milk	20	18	89 %
Sheepmeat	24	4	15 %
Pigmeat	130	117	89 %
Poultrymeat	86	77	89 %
Eggs	60	58	96 %
Food grains	179	257	144 %
Feed grains	930	651	70 %
Potatoes	250	245	98 %
Production (mill kcal)	2,154	2,154	100 %
GHG (mill kg CO2 equivalents)	4,337	2,602	60 %
Farmland used in agricultural production (mill. ha)	0.94	0.58	62 %
Grain	0.33	0.27	81 %
Food grain	0.05	0.07	144 %
Feed grain	0.29	0.21	71 %
Gras	0.60	0.31	51 %
Economic welfare (mill.NOK)	6,563	10,114	154 %
Producer subsidy estimate (mill. NOK)	19,247	12,980	67 %
Budget support	11,114	3,915	35 %
Market price support (mill. NOK)	8,133	9,066	111 %
CO2 tax rate (NOK per ton CO2 equiv.)	0	1,453	
Kcal subsidy rate (NOK per 1000 Kcal)	0	0.61	

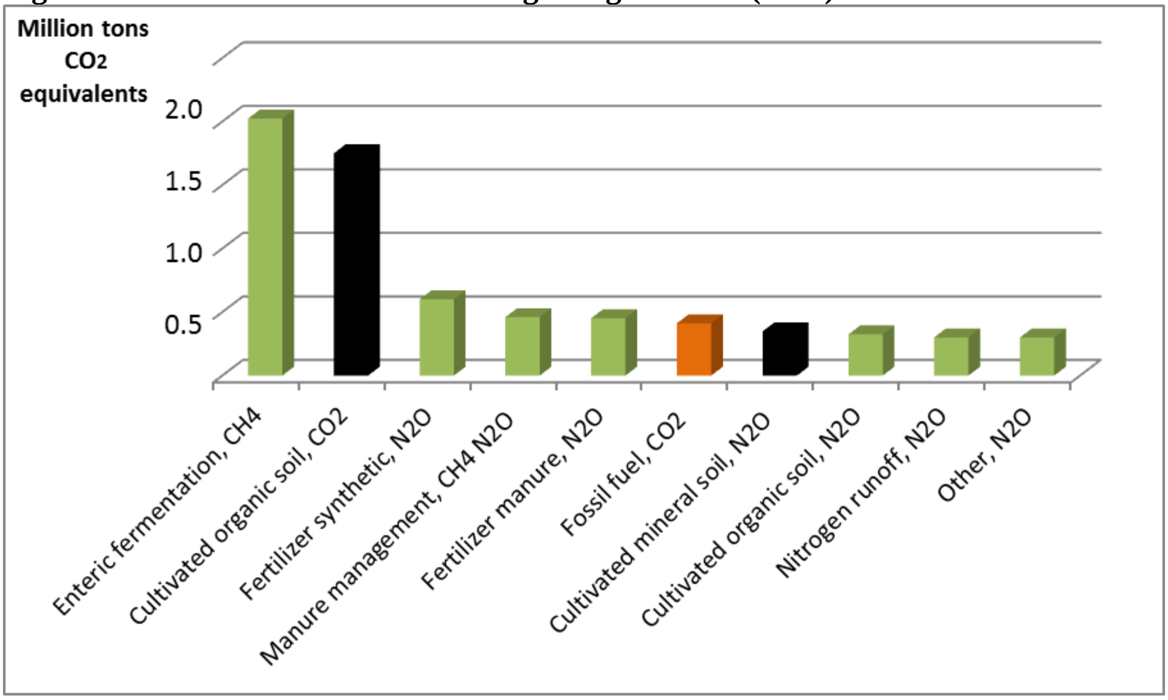
Source: Authors' calculations.

Table 5. Required net tax per produced unit (NOK per kg)

	Net carbon tax		**Net subsidy level**	
	NOK per kg	*% of current market price (farm level)*	*Current situation (NOK per kg)*	*Policy change α = 0.60; β = 1 (NOK per kg)*
Cow milk	0.64	114 %	2.56	1.92
Beef	28.31	167 %	61.85	33.54

Sheepmeat	36.89	194 %	109.72	72.83
Pigmeat	2.86	112 %	1.79	-1.07
Poultrymeat	2.21	112 %	2.98	0.77
Eggs	2.14	114 %	0.69	-1.45
Food grains	-0.84	65 %	1.36	2.20
Potatoes	0.37	107 %	0.18	-0.19

Figure 1: GHG emissions from Norwegian agriculture (2011)



Note: The green columns are emissions under Chapter 4 ‘Agriculture’ included in the Kyoto protocol. The black columns are emissions under Chapter 5 ‘Land use, land-use change and forestry’. For agriculture these include emissions from cultivated soil. The column for fossil fuel combustion belongs to Chapter 1 ‘Energy’. *Source*: KLIF (2013).

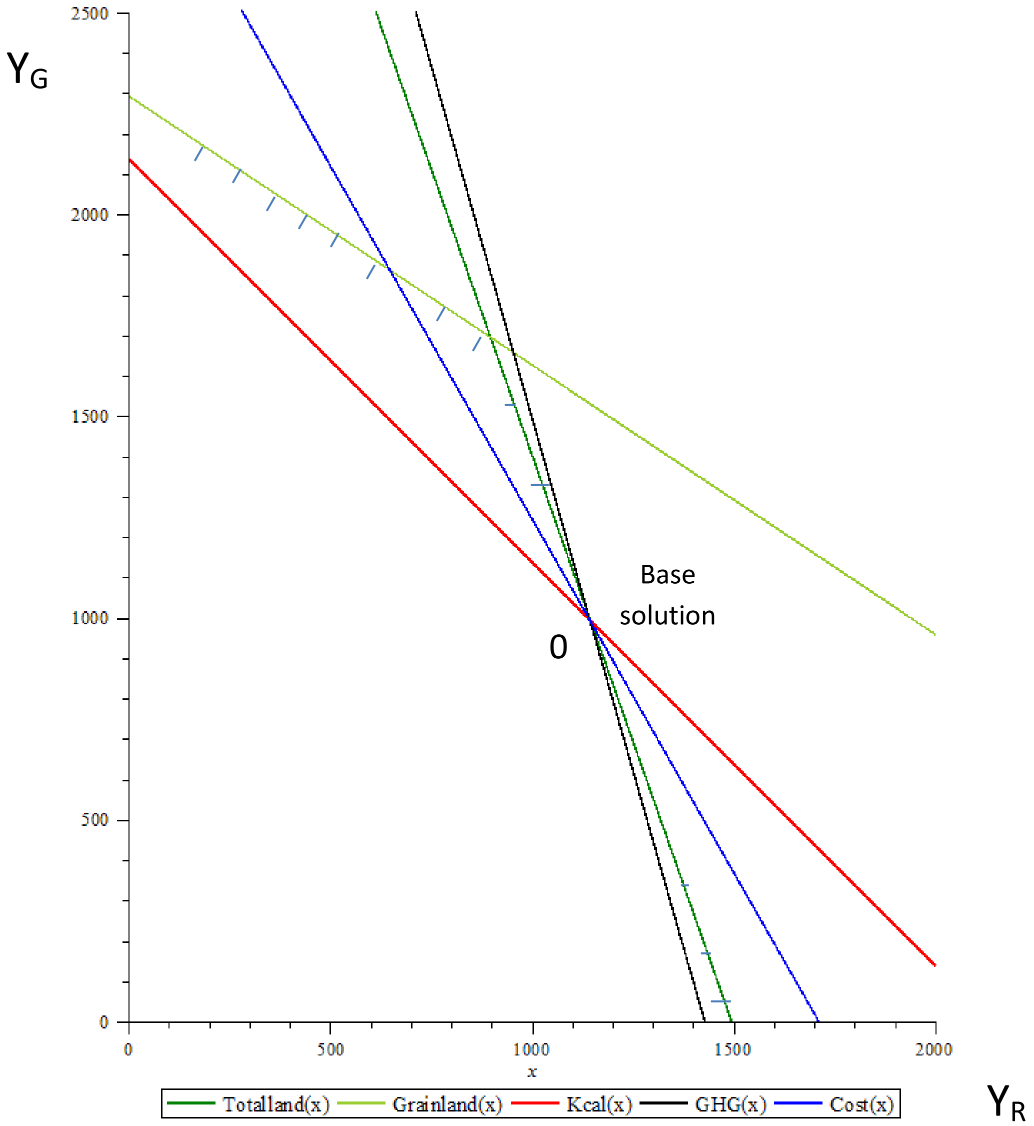


Figure 1. Base solution

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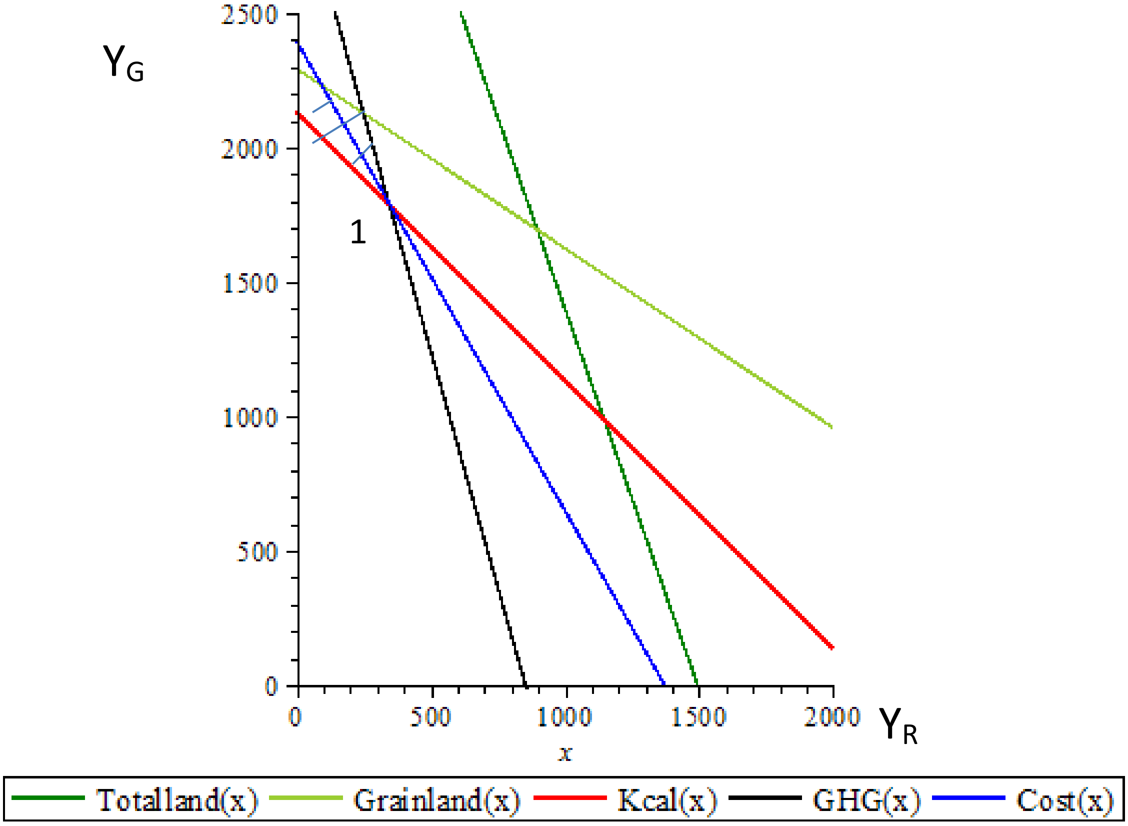

Figure 2. The effect of a 40% reduction in GHGs while maintaining calorie production