Energy Use in Agriculture:
A Modeling Approach to Evaluate Energy Reduction Policies

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Abstract

Agricultural production requires significant input of fossil fuels and other energy sources leading to negative external effects like emissions of CO_2. Measures to discourage energy consumption in the agricultural sector are contemplated upon and might increase costs of production activities. At the same time, energy cost rise due to market developments, also affecting the relative competitiveness of agricultural activities in favor of low energy input sub-sectors. Increasing energy related cost could reduce total energy consumption, but the extent of the reduction is uncertain.

The effects of increasing energy costs in EU27 on market quantities and prices as well as energy use in the agricultural sector will be investigated using the agricultural sector model CAPRI which was recently extended by an energy indicator related to production activities. This paper intends to demonstrate the functionality of a large scale agricultural sector model in simulations with respect to energy use

Key words: Energy Use in Agriculture, Energy Cost, Agricultural Sector Model

1. Introduction

The CAPRI modeling system will be applied for the ex-ante analysis. It combines about 250 regional agricultural supply models covering EU27 with a spatial, multi-commodity world market model being able to generate price and trade effects. The model has been applied multiple times for agricultural and trade policy impact assessment. The scenarios carried out in this study investigate the effects of implementing taxes on intermediate inputs depending on their energy content. The results of the CAPRI model allow the analysis of regional changes in differentiated land use and animal herd sizes, as well as commodity market outcomes and (partial) welfare measures differentiated by agents at national level. With the new energy indicator, it can be further investigated to which extent increasing energy cost lead to reduced energy consumption and overall increasing energy efficiency of the agricultural sector.

Calculations show that a tax of 1 Cent per MJ contained in a resource, which is analogous to about 50 Cent per liter diesel, would lead to an overall reduction of energy consumption around 10%. However the gain of overall efficiency seems to be limited. The drop in production is relatively balanced between the various production activities although the differences in total energy input and efficiency are significantly. This can be explained to a large extent by (absolutely) small demand elasticities and consequently strongly increasing product prices compensating quickly for cost increases.

2. Methodology

2.1. Quantifying Energy use in agriculture

The objective of the CAPRI energy indicator is to improve the existing CAPRI model in its capabilities to display environmental effects of agricultural production activities. Thereby, the requirements of non-renewable energy resources for agricultural production systems shall be analyzed. Energy input quantification follows process analysis within the methodology description of Cumulative Energy Demand (KEA) guideline N° 4600 (VDI, 1997). Thereby, the KEA states the entire demand of non-renewable energy resources, valued as primary energy, which arises in connection with the production, use and disposal of an economic good (product or service) or which may be attributed respectively to it in a causal relation (VDI, 1997). A precise definition of balancing boundary setting is carried out according to local, temporal and technological criteria and is an important foundation for the KEA. Due to the high complexity and multiplicity of some of the interactions between individual processes, systematic delimitation frequently poses a central problem for energy analysis. A detailed determination of all relevant energy and material flows in the service life of a product requires a separation of the components of the KEA right down to the individual processes. An energy balance in this context registers energy quantities or energy types respectively in Joule or Watt-hours, crossing the defined balance space boundaries during the period of analysis. The energy balance boundaries are identical with the material balance boundaries (VDI, 1997). In the CAPRI context, the input part of the KEA concept is underlying the energy assessment of agricultural production. Life cycle analysis (LCA), by integrating the KEA concept offers a suitable framework for energy assessment of CAPRI production activities. Therefore, guidelines such as ISO 14040 and 14044 are considered in the energy assessment process. Such procedure is based on process analysis. Setting the system borders precisely is an essential task in this concern.

Table 1: Energy module results structure

Parameter	**Parameter Unit**	**Description**	**Availability**
Energy per CAPRI activity unit	MJ/ha; MJ/head	Covers all energy requirements necessary for one CAPRI activity unit per year	Region-specific and activity-specific; weighted averages on NUTS-0 and EU level
Energy per CAPRI output unit	MJ/kg	All energy requirements for one CAPRI activity unit are divided by the output level; allocation between main product and by-products is carried out for a number of activities	Region-specific and activity-specific; weighted averages on NUTS-0 and EU level
Energy efficiency – Type “energy”	MJ/MJ	The output level of a CAPRI activity is assessed by its energy content, whereas allocation between main product and side-products is done for some activities. The result is divided by all energy requirements of the CAPRI activity unit. In short: Energy output (per kg) divided by energy input (per kg)	Region-specific and activity-specific; weighted averages on NUTS-0 and EU level
Energy balance	MJ	The output level of all CAPRI activities of a region are assessed by its energy contents (See Chapter 7.3.3) whereas allocation between main product and side-products is done for some activities and then sum up over the region. The input energy requirements for all CAPRI activities are multiplied with the relevant activity levels and then sum up over the region. The result shows energy requirements (INPUT) and energy output (OUTPUT). Imports and exports of energy can be shown separately.	Aggregated on EU level
Energy requirements-overview	MJ/ha; MJ/head	On an activity-based, regional level, the composition of total energy requirements can be shown on an aggregated level.	Region-specific and activity-specific; weighted averages on NUTS-0 level
Energy requirements-detail	MJ/ha; MJ/head	On an activity-based, regional level, the composition of total energy requirements can be shown on in detail.	Region-specific and activity-specific; weighted averages on NUTS-0 level
Energy input units	Input unit/ha; Input unit/head	On an activity-based, regional level, the composition of input units driving the energy needs can be shown in detail.	Region-specific and activity-specific; weighted averages on NUTS-0 level
Energy content products	MJ/kg product	On an activity-based level, the energy content for products can be shown; energy assessment of output is based on this parameter; Energy content is assumed being equal throughout all NUTS-II regions.	Activity-specific

Source: CAPRI Modelling System

The connecting link between process-based material flows and the energy requirement analysis are energy content factors. Life cycle inventories of agricultural production systems are the necessary tool therefore. The role of inventories such as ecoinvent (2003) is to provide modules for infrastructure and inputs used in agricultural production necessary for modeling production systems. In the case of the

CAPRI energy module, several aspects concerning inventories had to be considered. On the one hand, a broad range of different sources provide inventory databases designed for different countries in the agricultural context. On the other hand, to use a uniform methodological basis, a basic decision for inventories analysed by ecoinvent (2003) was taken. Firstly, a great number of single inventories (direct and indirect energy sources as well as agricultural processes) had been analysed. Secondly, the inventories being used are updated regularly and by using SALCA061 (2006) database for CAPRI energy indicator, a most recent version of the inventories was used. Thirdly, special analysis for the CAPRI energy module such as quantifying energy use for stables for animal production activities was carried out using the underlying methodology of ecoinvent database in order to consider specifics of CAPRI. Nevertheless, the ecoinvent agricultural inventories have been compiled mainly in a Swiss context using background data of Swiss agriculture. In order to use these inventories for CAPRI, adjustments have been made. Some minor differences in the energy assessment between CAPRI energy module and other literature sources cannot be avoided. The reason can be in the reference period of the data (most literature data is of some years age) or in the Swiss-based approach of the inventories.

Total energy requirements are calculated by summing up the energy requirements for the input quantities of mineral fertilizer, direct energy sources, machinery, building, plant protection, seeds, production support systems (such as irrigation or grain drying) and others. Special attention is paid to keep up consistencies concerning young animals and feeding stuff energy requirements.The results of the CAPRI energy module can be displayed in various ways and on different levels. Table 1 gives an overview.

2.2. The Agricultural Sector Model CAPRI

To give a brief overview on key properties of this system we note that the economic model is split into two major modules. The *supply module* consists of independent aggregate non-linear programming models representing activities of all farmers at regional or farm type level captured by the Economic Accounts for Agriculture (EAA). The programming models follow a hybrid approach, as they combine a Leontief-technology for variable costs covering a low and high yield variant for the different production activities with a non-linear cost function which captures among others the effects of labour and capital on farmers' decisions. The non-linear cost function allows for perfect calibration of the models and a smooth simulation response as is plausible for observations on aggregate behaviour. The models capture in considerable detail the current premiums paid under CAP and a module with feeding activities covering nutrient requirements of animals. Main constraints outside the feed block are arable and grassland, set-aside obligations and milk quotas. Prices are exogenous in the supply module and provided by the market module.

The module for marketable agricultural outputs is a spatial, non-stochastic global multi-commodity model for about 40 primary and processed agricultural products, covering about 40 countries or country blocks in 18 trading blocks. Bi-lateral trade flows and attached prices are modelled based on the Armington assumptions (Armington, 1969). The behavioural functions for supply, feed, processing and human consumption apply flexible functional forms where calibration algorithms ensure compliance with micro-economic theory. The parameters are synthetic, i.e. to a large extent taken from the literature, other modelling systems or own expert assessments. Policy instruments cover Product Support Equivalents and Consumer Support Equivalents (PSE/CSE) from the OECD, (bi-lateral) tariffs, the Tariff Rate Quota (TRQ) mechanism and, for the EU, intervention stocks and subsidized exports. This module allows for market analysis at global, EU and national scale, including a full assessment of price effects in all regions as a consequence to changes in exogenous inputs (e.g. policy shifts).

The CAPRI model has various advantages and disadvantages that should be mentioned to allow an appropriate interpretation of the scenario results. Advantageous features of the modelling system are consideration of price effects and coverage of the entire European Union at a quite detailed Nuts2 level. The most considerable disadvantage is the very limited description of alternative technologies.

Hence the model will primarily change the production program as consequence of rising energy cost. In reality farmers have additional potential to reduce their energy use without changing their production program, e.g. switching from ploughing to conservation tilling or selective application of fertilizers in order to reduce over fertilization. Against this background the following model results have to be considered as an extreme solution. In Chapter 3 we will refer to this point and mention whether a specific model result should be interpreted as a maximum or minimum effect.

2.3. Definition and Implementation of Scenarios

2.3.1. Reference Scenario

The reference scenario, often called “baseline” is supposed to describe the most probable situation of the European agricultural sector in 2013.This scenario used as comparison points or comparison time series for countervailing analysis. The baseline may be interpreted as a projection in time covering the most probable future development or the European agricultural sector under the status-quo policy and including all future changes already foreseen in the current legislation.

The projection tool is fed by forecasts from different experts or modelling tools, as well by trend forecasts using data from the ‘COCO’ database (Britz 2002) as ex-post information. Trend variables for baseline generation in the model are mainly constructed out of expert data on projections (e.g. FAO, European Commission or World Bank) and linear trends of data contained in the CAPRI data base. Nonetheless it is to be acknowledged here that the trend remain mechanical in that they try to respect technological relationships but remain ignorant about behavioural functions or policy developments.
Due to the complexity of the baseline generation process the reference scenario underlying this study does not account for recently increasing prices and demand for agricultural products as well as the foreseen abolition of obligatory set aside.

2.3.2. Increasing Energy cost

The CAPRI supply model is based on positive mathematical programming:

$$\max_{x_j \geq 0} z = \sum_{j=1}^{n} \left(r_j - c_j \right) x_j - \sum_j x_j \left(\alpha_j + \tfrac{1}{2} \sum_k \left(\beta_{jk} x_k \right) \right)$$

$$s.t. \sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \left[\lambda_i \right]$$

j activities
r revenu
c variable cost
x production level
a input coefficients
b ressouce availabilty
α and β parameter from calbration
λ dual value of contraints

We assume that increasing energy cost only influence variable cost, i.e. some additional cost c^* calculated in the scenario preparation enter the objective function.

$$\max_{x_j \geq 0} z = \sum_{j=1}^{n} \left(r_j - c_j - c_j^* \right) x_j - \sum_j x_j \left(\alpha_j + \tfrac{1}{2} \sum_k \left(\beta_{jk} x_k \right) \right)$$

$$s.t. \sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \left[\lambda_i \right]$$

c^* additional variable cost

As a consequence of introducing additional costs the optimal production level and hence the supply of agricultural goods will change. Following the market model determines demand and prices based on changed supply. This again alters the revenues in the supply part. Iterative solutions of market and supply model finally lead to equilibrium.
In order to evaluate effects of increasing energy cost we stepwise introduce additional cost – proportional to the energy consumption of an activity – in the objective of the supply model. This approach assumes that input prices increase depending on their energy content. Instead of changing prices for specific resources we assumed additional cost of 0.1, 0.5, 1 and 1.5 Cent per MJ of fossil energy consumption.
Table 2: relevant increasing energy cost scenarios. Table 2 gives an overview of relevant scenarios and illustrates the abstract value Cent per MJ by translation to additional cost per litre Diesel, kg N_2 or ha wheat. Rising cost in the range of 0.5 ct/MJ have been observed recently and further increase is quite conceivable.

Table 2: relevant increasing energy cost scenarios

Scenario definition		illustration of cost increase		
scenario name	additional cost	per litre Diesel	per kg N	per ha wheat (EU average)
Scenario0.1	0.1 ct/MJ	5ct	6ct	17 €
Scenario0.5	0.5 ct/MJ	23ct	30ct	86 €
Scenario1.0	1.0 ct/MJ	46ct	59ct	173 €
Scenario1.5	1.5 ct/MJ	69ct	88ct	259 €

2.3.3. Variation in obligatory seta aside rate

If rising input prises would not lead to decreasing energy consumption in agriculture policy makers might think about changes in obligatory set aside regulations in order to reduce emissions. In our study we investigate effects of increasing obligatory set aside by 50% and 100% assuming that existing exceptions, small producer regulation and non-food production on set aside, are engaged by farmers comparable to the reference situation.
As current considerations for other reasons suggest an abolition of obligatory set aside we carried out a simulations reducing obligatory set aside in combination with increasing energy cost of 1ct/MJ.

Table 3 : relevant set aside scenarios

Scenario definition		
scenario name	obligatory set aside (relative to reference)	additional cost
Seta50	50%	-
Seta100	100%	-
Seta00_1.0	0%	1.0 ct/MJ

3. Model Results

The following subsections will discuss results of the various scenarios describes before. Main focus will be given the increasing cost energy scenarios while the reference situation will only be briefly discussed. Detailed analysis of the reference situation can be found in Kränzlein (2007).

3.1. Reference Scenario

The reference scenario or baseline is mainly used to quantify changes in countervailing scenarios. In the following sections several results from the reference situation will be shown. Beforehand we would like to present some results of the CAPRI energy module describing energy consumption and efficiency to create a better understanding of model reactions in countervailing analysis.

Table 4 and Table 5 show average European energy consumption of selected crop and animal activities. Especially animal activities need significant amounts of energy in form of intermediate agricultural inputs. The assessment of energy content of intra-sectoral inputs is not based on their actual energy content but on use of energy for their production. This is important to note for the implementation of scenarios assuming increasing energy cost since intra-sectoral inputs have to be excluded when additional cost per MJ are calculated to avoid double counting.

Table 4: Energy consumption of selected crop activities

crop activities	variable input					fixed factors		intrasectoral
	Diesel	other fuels	electricity	plant protection	feed/fertilizer	buildings	machinery	seed
Cereals	4681.48	1401.43	2894.94	548.67	7779.08	216.04	3353.44	567.78
	21.8%	6.5%	13.5%	2.6%	36.3%	1.0%	15.6%	2.6%
	80.7%					16.6%		2.6%
Grain Maize	7551.17	8996.87	18242.14	522.41	10879.94	289.81	8010.61	315.05
	13.8%	16.4%	33.3%	1.0%	19.9%	0.5%	14.6%	0.6%
	84.3%					15.1%		0.6%
Potatoes	7657.96	173.97	2766.27	2585.81	7775.25	570.36	10614.15	4734.27
	20.8%	0.5%	7.5%	7.0%	21.1%	1.5%	28.8%	12.8%
	56.8%					30.3%		12.8%
Sugar Beet	6237.85	89.04	2569.77	1462.1	7863.91	300.04	6358	51.98
	25.0%	0.4%	10.3%	5.9%	31.5%	1.2%	25.5%	0.2%
	73.1%					26.7%		0.2%

Table 5: Energy consumption of selected animal activities

animal activities	Total [MJ]	variable input	fixed factors		intrasectoral	
		fuel and electricity	buildings	machinery	feed	young animal
Dairy Cows	36942.36	11912.215	5191.975	151.21	14722.785	4964.175
		32.2%	14.1%	0.4%	39.9%	13.4%
		32.2%	14.5%		53.3%	
Beef meat activities	21883.6	2031.93	3096.78	0	6493.79	10261.1
		9.3%	14.2%	0.0%	29.7%	46.9%
		9.3%	14.2%		76.6%	
Pig Fattening	3151.71	1152.8	96.86		998.56	903.48
		36.6%	3.1%	0.0%	31.7%	28.7%
		36.6%	3.1%		60.3%	
Pig Breeding	15427.21	7408.04	2051	0	5481.33	486.83
		48.0%	13.3%	0.0%	35.5%	3.2%
		48.0%	13.3%		38.7%	

Table 6 shows energy input and content for mayor agricultural products. An efficiency factor is calculated as ratio of energy content and input. It becomes clear that crops on arable land generally contain more energy in the marketable production that was used during cultivation. Especially Sugar beet and cereals have an outstanding energy balance compared to others. Vegetables and permanent crops are less favourable since often energy intensive greenhouse and irrigation systems are necessary. Animal products always contain less energy than spend in their production.

As European agriculture besides conserving energy is also supposed to produce significant amounts of food, i.e. energy for human nutrition, it would be appreciated if rising energy cost or other measures would lead to significant reduction of animal numbers and more direct consumption of cereals in human nutrition. Otherwise a decline in European agricultural production induced by increasing energy cost would have to be balanced by additional imports. From a global point of view this would only be a reallocation of emissions.

Table 6: agricultural products: energy input, -content and efficiency

	input domestic [MJ/kg or unit]	energy in product [MJ/kg or unit]	efficency [MJ/MJ]
Cereals	3.52	11.36	3.23
Soft wheat	2.71	11.74	4.33
Durum wheat	5.23	11.49	2.2
Rye and meslin	3.18	13.3	4.18
Barley	3.01	11.85	3.94
Oats	3.58	11.13	3.11
Grain maize	5.89	11.11	1.89
Other cereals	2.63	12.1	4.59
Oilseeds	5.8	15.12	2.61
Rape seed	5.07	15.28	3.01
Sunflower seed	8.15	15.28	1.87
Other arable field crops	0.87	2.73	3.14
Pulses	4.1	14	3.41
Potatoes	1.62	2.74	1.69
Sugar beet	0.43	2.38	5.53
Vegetables and Permanent crops	9.44	4.64	0.49
Tomatoes	8.2	0.81	0.1
Other vegetables	8.53	1.12	0.13
Apples pears and peaches	1.3	1.7	1.31
Citrus fruits	4.22	1.18	0.28
Olive for oil	12.62	36.81	2.92
Table wine	5.26	2.85	0.54
All other crops	1.13	0.36	0.32
Meat	37.78	7.18	0.19
Beef	65.87	5.75	0.09
Pork meat	35.86	8.43	0.24
Poultry meat	24.83	5.65	0.23
Other Animal products	4.67	1.63	0.35
Cow and buffalo milk	4.91	2	0.41
Eggs	19.39	5.89	0.3
own calculations based on the CAPRI energy module - selected crops			

3.2. Increasing Energy cost

The following sections will describe effects of increasing energy cost in more detail. We will see that increasing energy cost lead to a reduction of energy consumption in the agricultural sector and increase in efficiency. Following the coherence leading to decreasing energy use are shown by analysing land allocation and herd sizes. Finally market and welfare effects are presented.

3.2.1. Energy consumption and efficiency

Increasing energy cost lead to an quite significant reduction in total consumption up to 10% (Figure 1). Simultaneously the relation of energy input and output becomes favourable. This is remarkable since the limited description if alternative technologies in the CAPRI model should tend to underestimate potentials of energy saving.

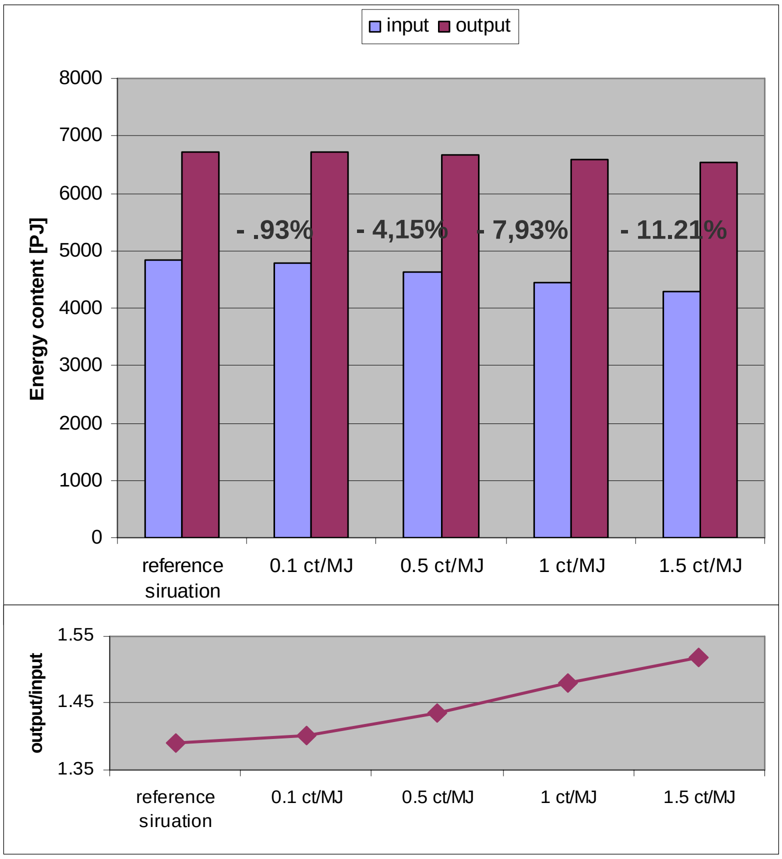

Figure 1: Total energy consumption and efficiency in different scenarios (increasing energy cost)

Regional differences of the simulated energy reduction are shown in Figure 2. European wide agricultural energy consumption decreases by 7.9%. While 25% of the regions show quite moderate decline less than 1%, in the most effected regions energy consumption drops by 25%. Thereby no coherence between decline in energy consumption and sectoral ratio of input and output is visible. This indicates that regional decrease in energy consumption is a combination of activity specific efficiency and the production pattern.

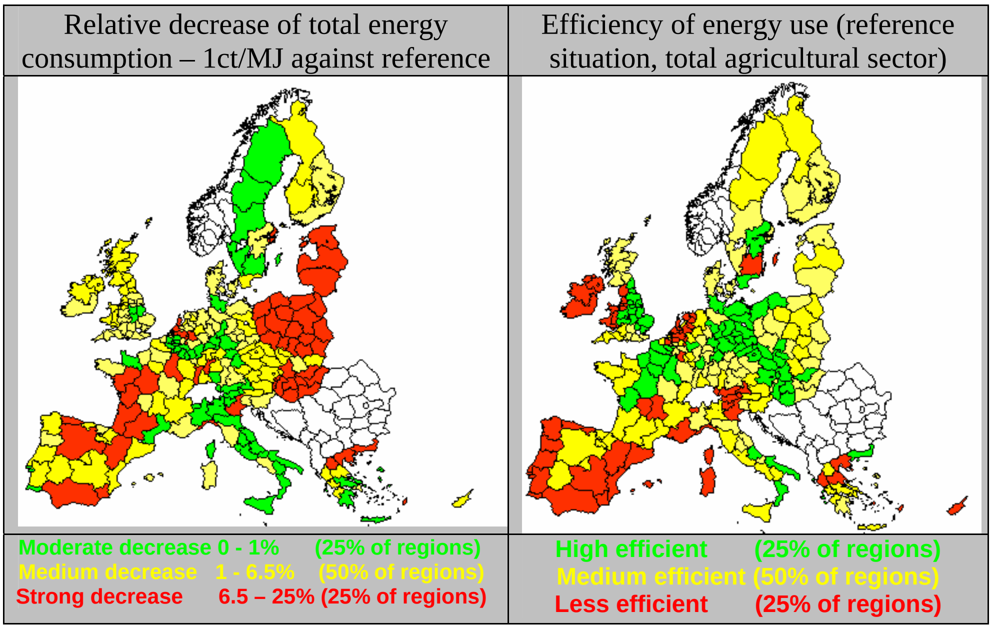

Figure 2 : Regional distribution of energy reduction

3.2.2. Land allocation and herd sizes

Increasing energy cost lead to decreasing production of arable crops. The idle land is used to some extend for fodder production but most of it will be fallow. The production of oilseeds is nearly constant as it is for several types of grains like soft wheat, rye and barley. The drop in total cereal production is mainly caused by decreasing maize production which requires significant amounts of energy for drying of grain in many regions. The production of other arable and permanent crops decreases clearly up to 4% in the various scenarios.

The herd sizes of meat producing activities - beef, pork and poultry - decrease in quite similar range up to 5%. The number of dairy cows is constant what reveals a still binding character of the milk quota system. Hence the drop of suckler cows is quite significant what keeps the young animal markets balanced.

The drop in production is relatively balanced between the various production activities although the differences in total energy input and efficiency are significantly. Especially animal herd sizes drop less than one might have expected against the background of energy efficiency. This can be explained to large extend by increasing market prices for these products.

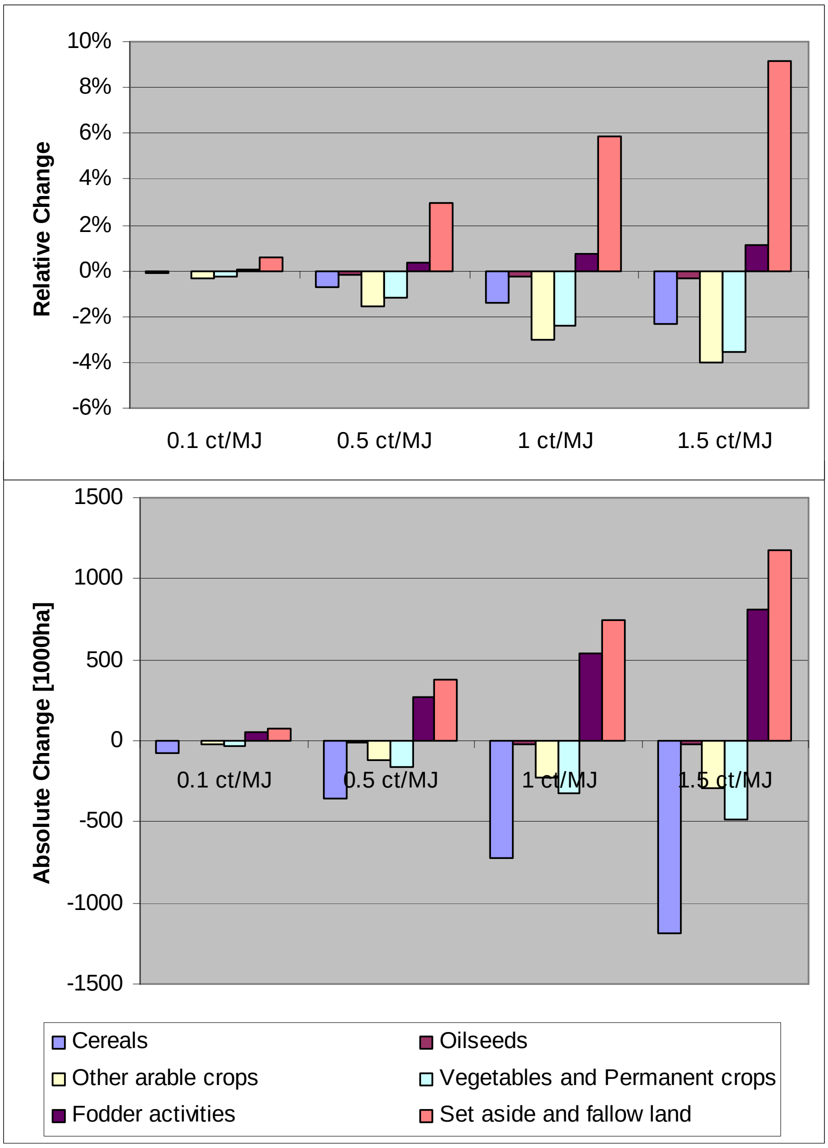

Figure 3: Change in land allocation

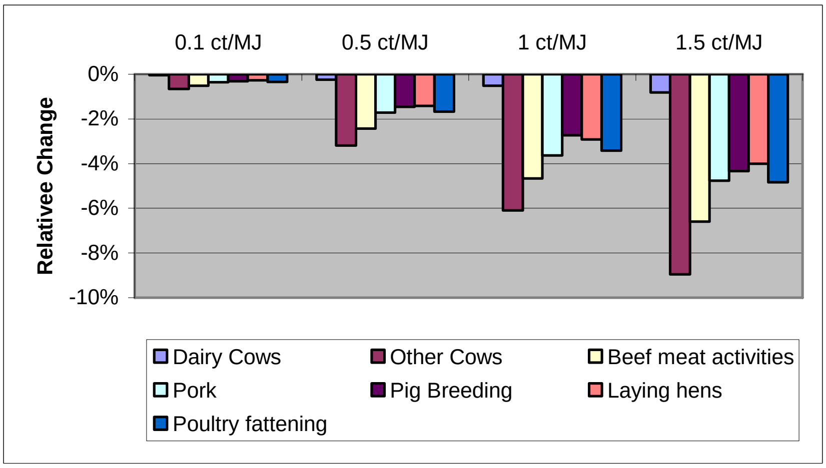

Figure 4 : Relative change in animal numbers

3.2.3. Market effects

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Table 7: Market effects – selected products and aggregates

	Reference Situation				1ct/MJ			
	Market price [€/t]	Supply- [1000 t]	Net trade [1000 t]	Demand [1000 t]	Market price [€/t]	Supply- [1000 t]	Net trade [1000 t]	Demand [1000 t]
Cereals	102.3	282371	20992	259837	102.92	273689	20374	250982
					0.65%	-8683	-617	-8855
Soft wheat	105.2	124226	17590	106630	104.63	123142	19051	104080
					-0.49%	-1084	1461	-2550
Rye and meslin	80.6	8754	213	8541	67.48	9050	289	8761
					-16.23%	296	76	220
Barley	98.2	58302	5711	52264	96.15	58903	6612	50894
					-2.11%	602	901	-1370
Grain maize	93.7	51714	-2201	52736	107.76	42605	-6718	48429
					15.05%	-9110	-4517	-4306
Oilseeds	222.6	20091	-42456	62548	221.74	20106	-42043	62150
					-0.39%	15	413	-398
Rape seed	226.0	15199	-4027	19227	224.8	15184	-4004	19188
					-0.51%	-15	23	-39
Sunflower seed	217.2	4276	-2071	6347	216.33	4354	-1989	6343
					-0.39%	78	82	-5
Other arable field crops	63.0	186221	4114	182107	65.9	178183	2669	175515
					4.65%	-8037	-1445	-6592
Potatoes	94.6	57150	4156	52994	107.59	51420	2498	48921
					13.68%	-5730	-1657	-4073
Sugar beet	45.5	125215	-146	125361	45.84	122722	-147	122869
					0.70%	-2493	-1	-2492
Vegetables and	597.4	140355	-13970	154313	627.01	136677	-14681	151346
					4.95%	-3678	-711	-2967
Tomatoes	365.1	18428	-287	18716	380.45	17335	-297	17631
					4.22%	-1094	-10	-1084
Apples pears and	520.8	16676	-392	17068	527.3	16678	-467	17145
					1.24%	3	-75	77
Citrus fruits	413.9	11367	-8849	20216	420.41	11276	-9209	20485
					1.58%	-91	-360	269
All other crops	136.8	239633	-268	239902	136.65	239626	-274	239901
					-0.10%	-7	-6	-1
Meat	1640.3	42436	487	41949	1814.47	41095	-315	41411
					10.62%	-1341	-803	-538
Beef	2774.0	7929	-362	8292	3035.39	7722	-499	8222
					9.42%	-207	-137	-70
Pork meat	1344.4	21710	883	20827	1503.88	20942	372	20570
					11.87%	-768	-510	-257
Other Animal products	261.5	204947	1210	203737	264.73	203825	1118	202707
					1.24%	-1122	-92	-1030
Cow and buffalo milk	256.4	143057	0	143057	258.33	142601	0	142601
					0.77%	-456	0	-456
Eggs	1088.5	7088	1002	6086	1155.7	6920	930	5990
					6.18%	-168	-72	-96

3.3. Variation in obligatory seta aside rate

Variation in obligatory set aside lead to almost no significant change in energy input comparing increasing set aside rates against reference situation and abolition of obligatory set aside within an assumed cost increase of 1ct/MJ. Whereas the energy content in agricultural products changes noticeably leading to quite significant differences in input output ration. The most favourable ratio is simulated for the situation with no obligators set aside and increasing energy cost.

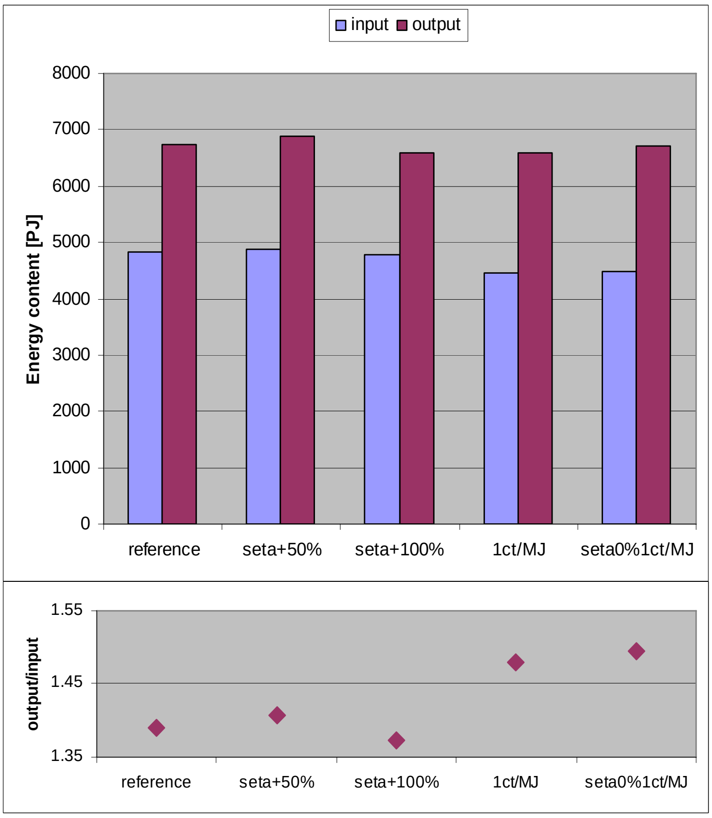


Figure 5: Total energy consumption in different scenarios (variation of set aside)

These findings become comprehensible when regional efficiency of production is compared to impacts of changes in obligatory set aside (see Figure 6). Changes in obligatory set aside rate do not necessarily lead to an increase of actual (total) set aside for following reasons:

- EU10 countries have actually no set aside obligation.
- Small producers are excluded from the obligatory set aside regulations, i.e. regions where significant numbers of farms produce little amounts of cereals are hardly affected. This holds mainly for Ireland, Belgium, Netherlands, Italy and Greece.
- In several regions the farmers opted voluntary to put parts of their land in set aside. Increasing obligatory set aside has minor effects since land was anyway not cultivated. This hold mainly for less favourable regions in northern and southern Europe.

Hence the strongest change in actual set aside is apparent in North West France, Germany, Denmark and Parts of Great Britain. These regions are at the same time superior with respect to the efficiency in cereals production.

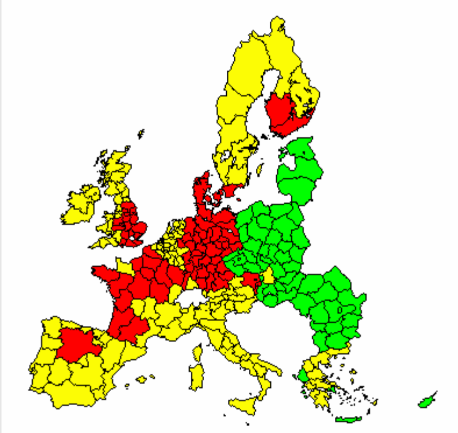
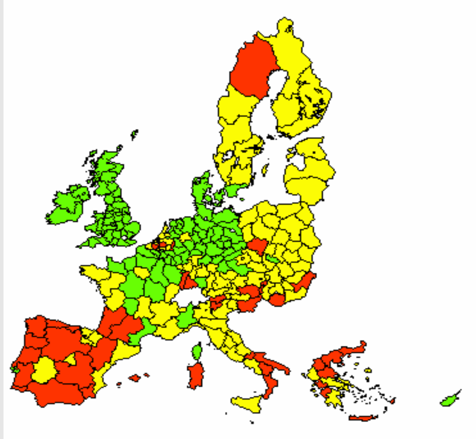
Increase in set aside and fallow land (% of total agricultural area)	Efficiency of cereal production
	
Low increase (25% of regions) Medium increase (50% of regions) Strong inrease (25% of regions)	High efficient (25% of regions) Medium efficient (50% of regions) Less efficient (25% of regions)

Figure 6 : Increase of set aside and efficiency of production

Increasing obligators set aside tends to shift production from efficient to less favourable regions and vice versa. Consequently from the "efficiency" point of view an abolition of set aside would be appreciated.

4. Conclusions

The objective of the recently developed CAPRI energy indicator was to improve the existing CAPRI model in its capabilities to display environmental effects of agricultural production activities and allow for analysis of interdependencies. The scenarios underlying this paper demonstrate the functionally of he tool and lead to some findings and recommendations that should be investigated in more detail in future:

- Increasing energy prices lead to quite significant drop of energy consumption in agriculture
- Consumers behavior is crucial since demand elasticities are quite small
- The abolition of obligatory set might be desirable since productive and energy efficient locations are mainly effected.

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