Greenhouse gas emissions from land use changes due to the adoption of the EU biofuel objectives in Spain.

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Objetives

- To evaluate and quantify
  - The amount of land needed to grow the raw materials for the required amount of biofuel production according to the national and EU penetration goals in Spain.
  - The availability of set aside, idle land or land productivity increase in Spain in order to meet this land demand for biofuel production
  - The resulting land use changes
  - The greenhouse gas emissions from these land use changes due to the adoption of the national and EU objectives in Spain

GHG balance of biofuel chains. Methodology

Life Cycle Assessment (UNE-EN-ISO 14040-44)

Studied systems.

- **System E85**: production and use of the blend E85 (85% ethanol and 15% gasoline)
- **System gasoline**: production and use of unleaded gasoline 95 50 ppm S in a flexible fuel passenger car, (Ford Focus 1.6i 16 V Zetec Flexifuel) driving according to the driven cycle defined in the 98/69/EC Directive;
- **System Biodiesel**: Production and use of pure biodiesel from oil seeds.
- **System Diesel**: Production and use of diesel from crude oil 50 ppm S in a diesel passenger car (Ford Focus 1.8 Tddi 90 HP), driving according to the driven cycle defined in the 98/69/EC Directive

Functional unit.

The amount of fuel expressed in MJ of each fuel needed to drive one kilometre

E85: **2.24** MJ/km
Gasoline: **2.36** MJ/km
Diesel: **1.89** MJ/km
Biodiesel : **1.89** MJ/km

Sources of data.

- **AOP.** Data related to the extraction, transport and oil refining for the production of gasoline and diesel in Spanish refineries
- **Higher Technical School of Agricultural Engineering (ETSIA)** of the Madrid Polytechnic University. Data related to the stages of agricultural production of cereals and oil seeds in Spain.
- Data related to the agricultural production of imported seeds was taken from the literature.
- **Abengoa Bioenergía.** Data related to its ethanol production plants located in Cartagena and Curtis
- **Bunge-MOYRESA.** Data related to oil extraction processes from oil seeds.
- **ACCIONA** Biocombustibles. Data related to the biodiesel production processes
- **Ford.** Data related to emissions and fuel consumption by the reference vehicles with the different types of fuel under consideration

Raw materials

Bioethanol production:

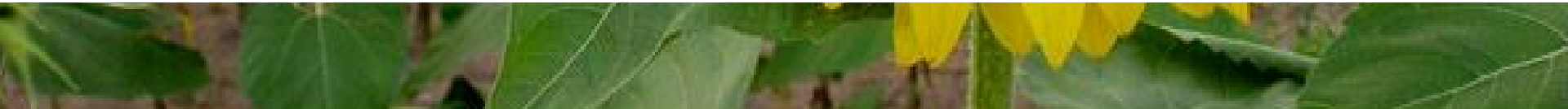
- domestically produced cereal crops (wheat and barley)
- Imported cereals from Europe (UK and Denmark)

Biodiesel production:

- Domestically produced sunflower and rapeseed
- Imported soybeans (USA), rapeseed (France), and palm oil (Thailand)

Base case

- **Bioethanol** from domestically produced wheat and barley
- **Biodiesel** from a mixture of:
  - 40% soybean oil (imported seeds)
  - 25% rapeseed oil (5% domestically produced rapeseed and 95% imported rapeseed)
  - 25% imported palm oil
  - 10% sunflower oil (domestically produced seeds)

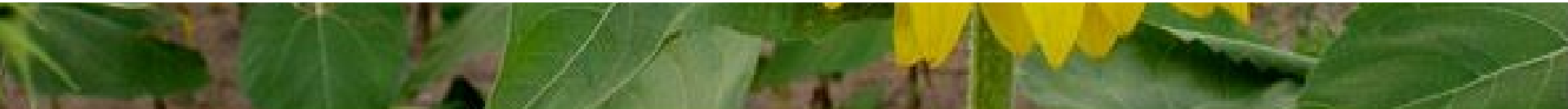


GHG emissions from land use change. Methodology

Simplified methodology similar to that proposed by Fritsche et al. to calculate the ILUC factor

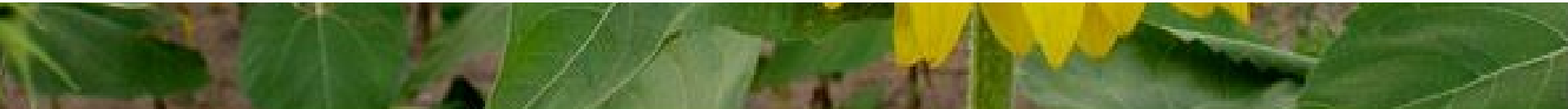
Land use calculation hypothesis

- Productivity of agriculture in the countries of origin of the raw materials
- Transformation efficiencies of processes
- Land use avoided due to the production of the different co- products
- Only first generation biofuels



Land availability

- Set aside land, other fallow or degraded land available in Spain
- Land diverted from cultivation of other crops (CAP sugar reform) in Spain
- Increase in productivity of some crops (more productive palm trees in Malaysia). In Europe or USA it has been assumed no increase in productivity
- Avoided land use due to coproducts utilization considered to compute net land requirements
- No idle land available in other countries to meet the additional biofuel demand for Spain -> Increase the cultivated land



Land use changes hypothesis (1/3)

- The part of the raw material demand that cannot be met from set aside, fallow or marginal land in Spain and from increase in productivity will cause a displacement of other products

- It has been assumed that the market for agricultural commodities is global -> the countries that would increase production are the main exporters:
  - Soybeans: USA
  - Rapeseed: Canada
  - Palm: Malaysia

Land use changes hypothesis (2/3)

➢ The most likely land use change in each country considered taking into account the actual land use change produced in each country when crops where last expanding as provided by Searchinger et al. :

- USA: grassland to cropland
- Canada: grassland to cropland
- Malaysia: open forest to palm oil plantation

➢ These land use changes contradict the sustainability criteria of the REN Directive. They have been considered as indirect.

Land use changes hypothesis (3/3)

- The C losses per ha due to these land use changes are taken from Searchinger et al. :
  - USA: grassland to cropland: 30 t C/ha
  - Canada: grassland to cropland: 54 t C/ha
  - Malaysia: open forest to palm oil plantation: 83 t C/ha
- Several amortization times (from 20 to 100) have been considered.

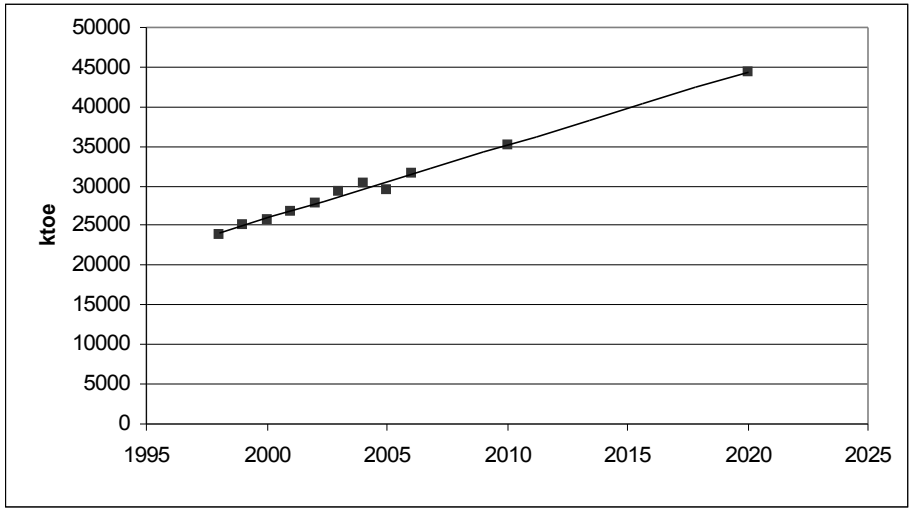
Biofuel goals in Spain.

Biofuels Directive 2003/30/CE

2010: 5.75% total vehicle fuel consumption

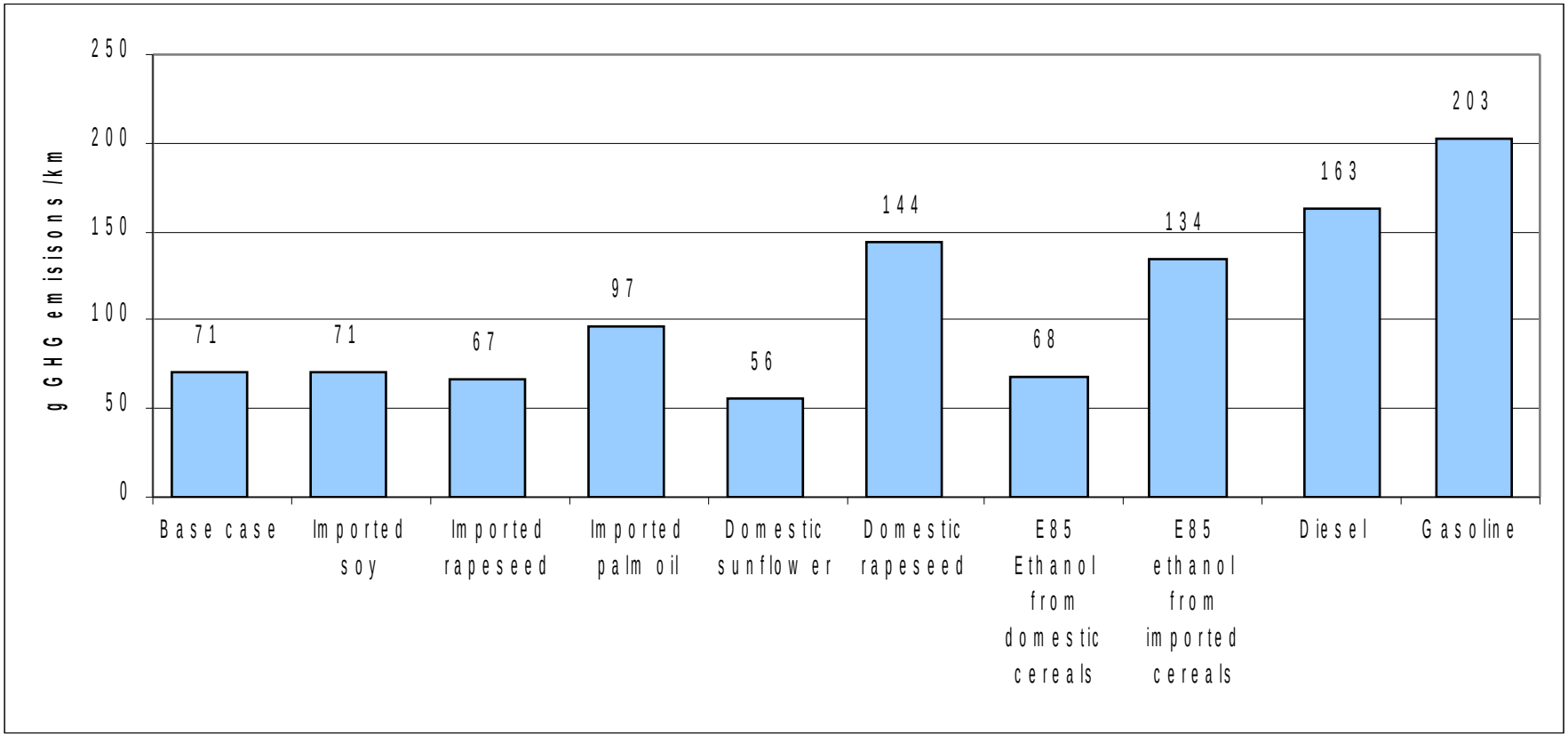
REN Directive Dec 2008

2020: 10% total vehicle fuel consumption

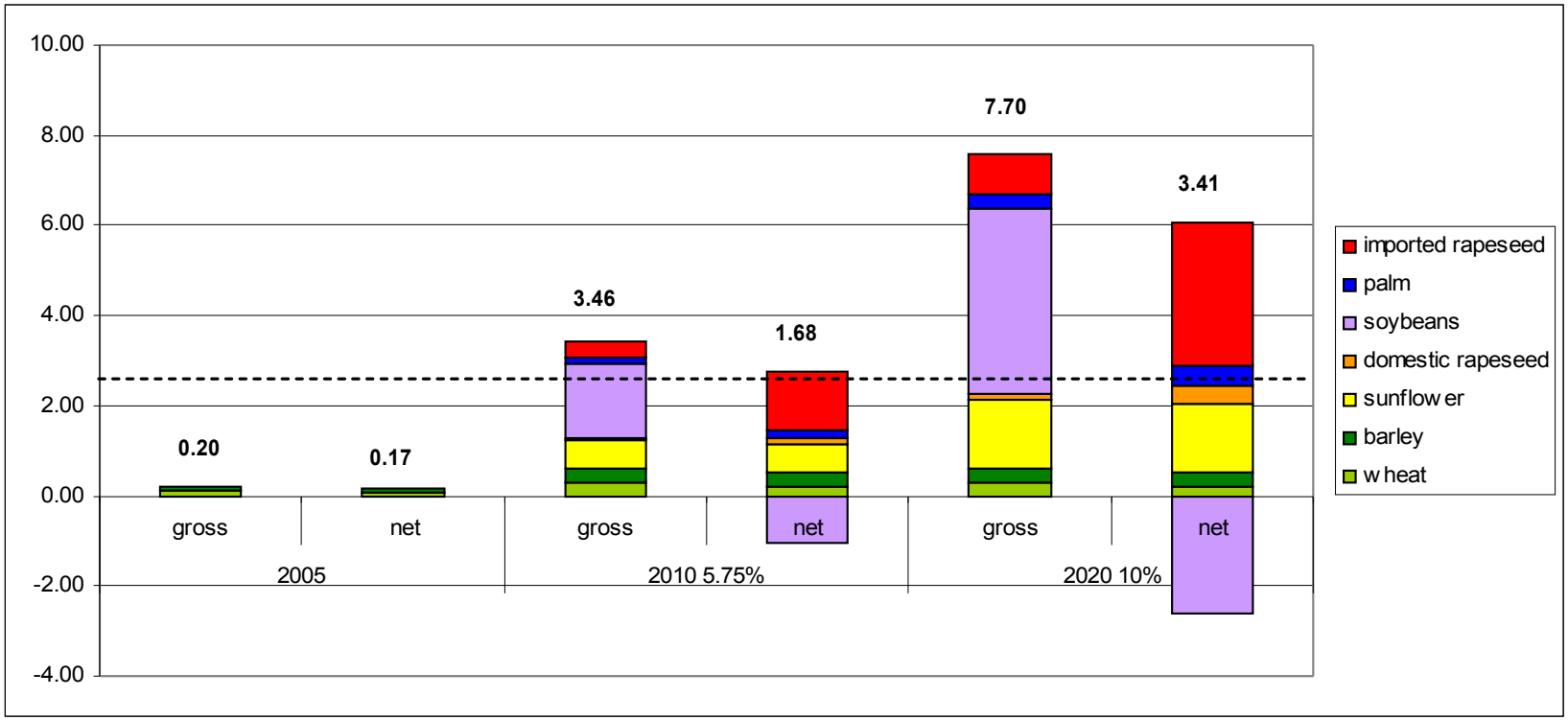


2010 and 2020 fuel consumption estimation: Simple linear extrapolation of the observed tendencies from year 1998 until year 2006

Results. GHG emissions without land use change consideration



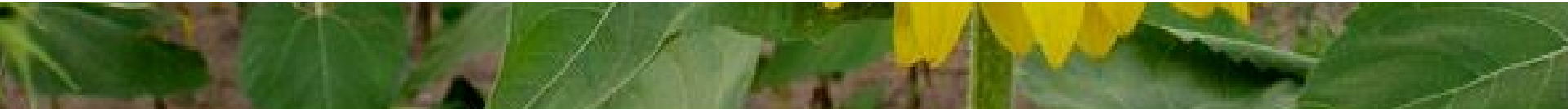
Results. Land use requirements (ha)(1/3)



Net land requirements: considering land use avoided due to coproducts utilization

Results. Land use requirements (2/3)

- Land available in Spain in enough to grow:
  - The cereals needed to produce bioethanol up to 2020
  - The sunflower and domestic rapeseed considered in our base case assumption to produce biodiesel domestically.
  - The rest of the seeds needed to produce the required amount of biodiesel will need to be imported and will cause indirect land use change.

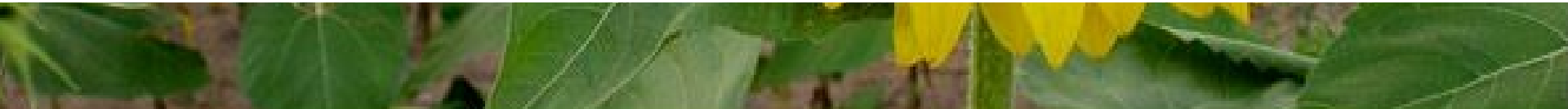


Results. Land use requirements and land displaced (3/3)

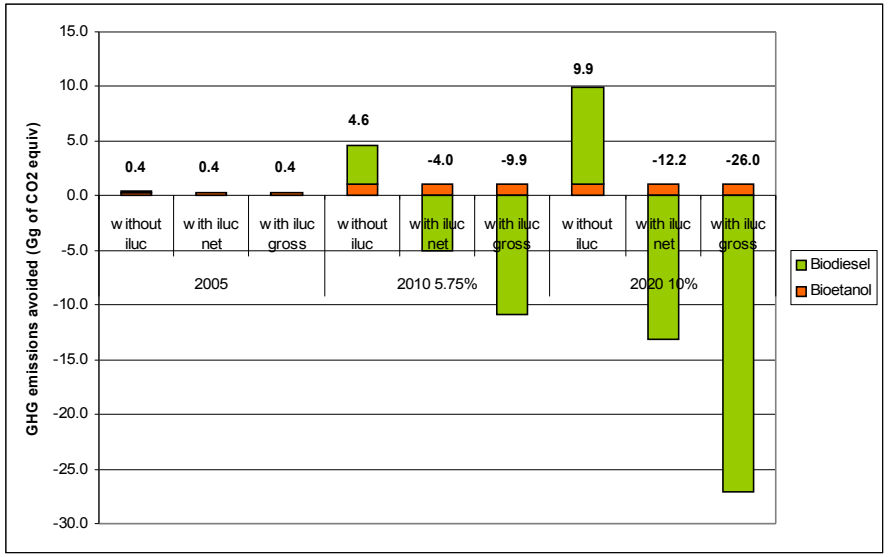
		Bioethanol	Biodiesel
2005	Land required (10^{10} m^2)	0.16	0.004
	Land displaced (10^{10} m^2)	-	0.001
	ILUC factor	0%	29%
2010	Land required (10^{10} m^2)	0.52	1.16
	Land displaced (10^{10} m^2)	-	0.33
	ILUC factor	0%	29%
2020	Land required (10^{10} m^2)	0.52	2.89
	Land displaced (10^{10} m^2)	-	0.97
	ILUC factor	0%	34%

Results. GHG emissions due to indirect land use change (g CO2 equiv/MJ).

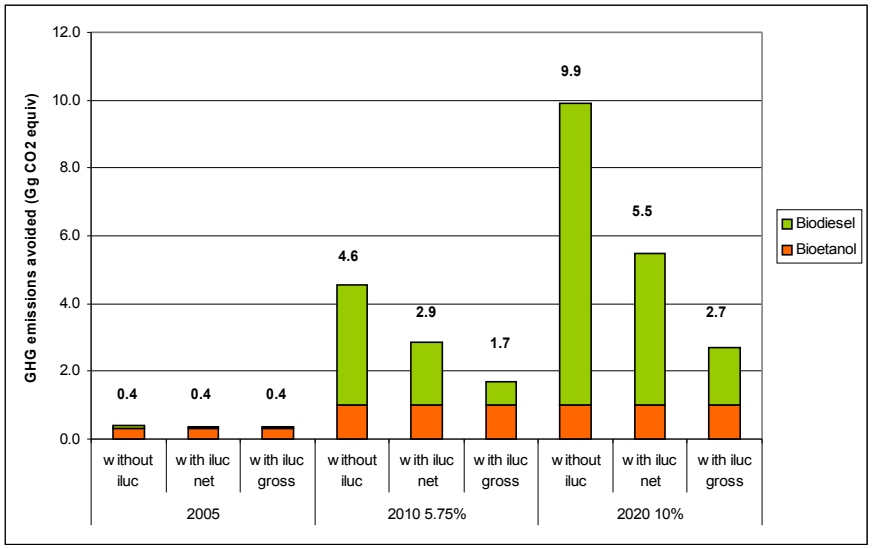
		2005		2010		2020	
	Life cycle emissions without ILUC	ILUC emissions 100 years	ILUC emissions 20 years	ILUC emissions 100 years	ILUC emissions 20 years	ILUC emissions 100 years	ILUC emissions 20 years
Bioethanol	19	0	0	0	0	0	0
Biodiesel	38	25	125	25	125	26	129



Results. GHG emissions avoided (1/2).

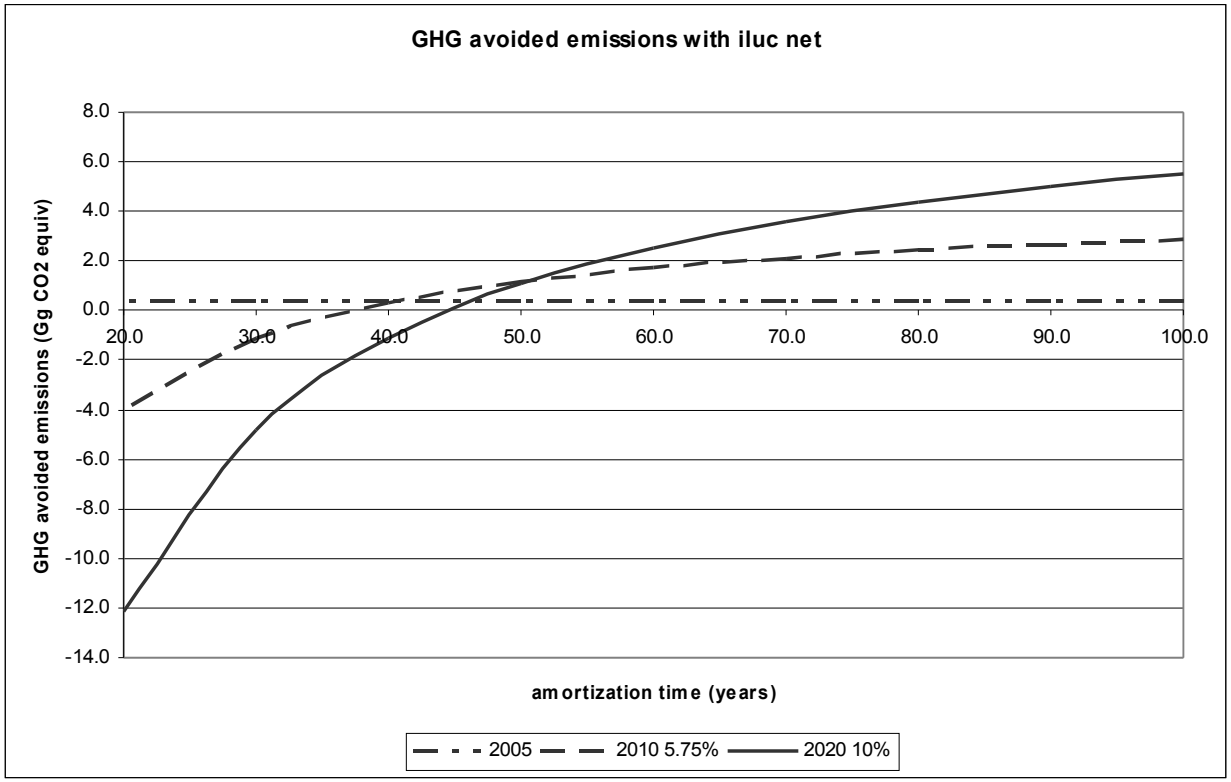


Amortization time : 20 years



Amortization time : 100 years

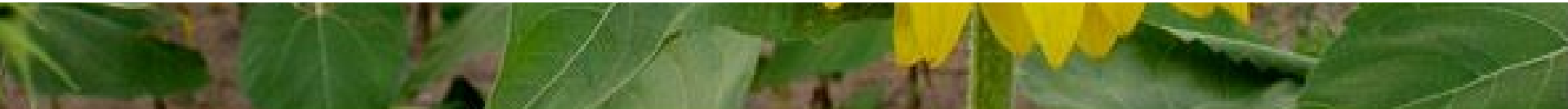
Results. GHG emissions avoided (2/2).



Conclusions (1/3).

- Land available in Spain in enough to grow:
  - The cereals needed to produce bioethanol up to 2020
  - The sunflower and domestic rapeseed considered in our base case assumption to produce biodiesel domestically.
  - The rest of the seeds needed to produce the required amount of biodiesel will need to be imported and will cause indirect land use change.

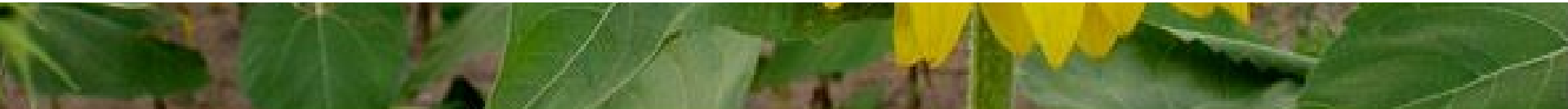
- Bioethanol production will not displace any land (ILUC factor 0%), whereas biodiesel production will displace some amounts of land and the calculated ILUC factors are 29% and 34% in 2010 and 2020 respectively.



Conclusions (2/3).

- The additional GHG emissions due to ILUC have been calculated and are significant in the case of biodiesel production (25-129 g CO2 equiv.MJ-1 of biodiesel, which represent 67%-344% of GHG emissions without ILUC consideration).

- The substitution of conventional fossil fuels by biofuels if land use displacement effects are not considered, can avoid the emissions of 4.6 Gg (2010) and 9.9 Gg (2020) of GHG per year. When gross or net land use change effects are considered these quantities are much more reduced and can be even negative if an amortization time lower than 38 years is assumed.



Conclusions (3/3).

- Results are very sensitive to the amortization time selected as well as to the type of land use changes assumed to be taking place. Further research is needed in order to investigate the magnitude of these uncertainties.