# LCA of Ethanol Production and Use: the Lombardy (Italy) Case Study

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## INTRODUCTION

The environmental impacts of biofuels are very variable

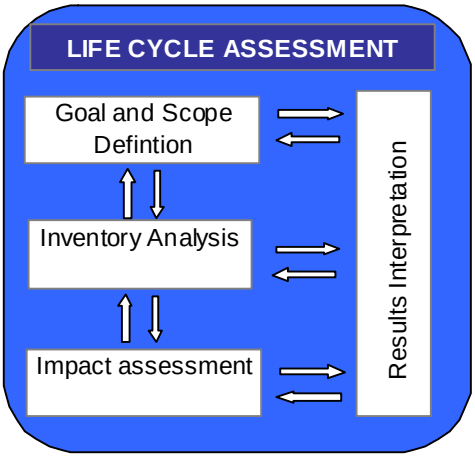
They depend very much on location, farming techniques, transformation pathways, and final use of by-products

**A case-by-case assessment might be required**

**LCA (Life Cycle Assessment) methodology**

**W_T_W (Well To Wheel-*cradle to grave*) approach**

## *Life Cycle Assessment LCA*




**ISO 14040:2006**

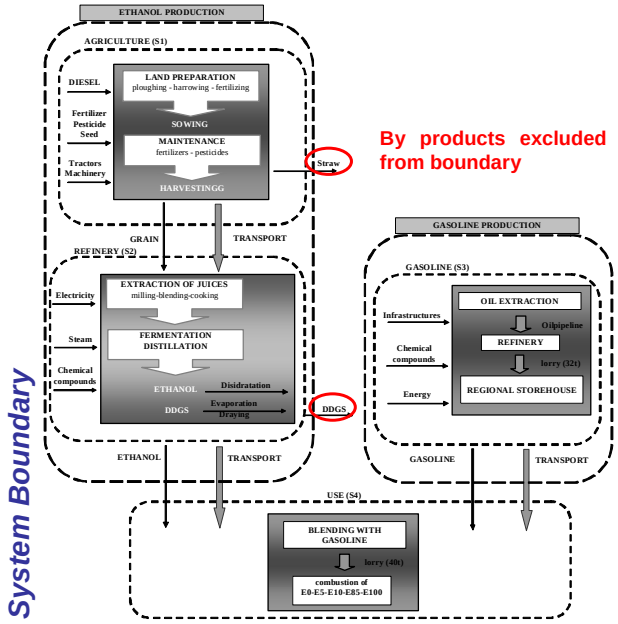
## *LCA Goal and Scope Definition*

**Bioethanol**: **environmental impact** and **energy request** of production and use of ethanol produced from wheat grain, cultivated in Lombardy and used in 5 different blends

- **E0: pure Gasoline**
- **E5: 5%Ethanol-95%Gasoline**
- **E10: 10%Ethanol-90%Gasoline**
- **E85: 85%Ethanol-15%Gasoline**
- **E100: pure Ethanol**

**FU (Functional Unit):** ***amount of fuel needed to run the reference distance (kg/km)***

## LCA
## Goal and Scope Definition




By products excluded from boundary

**S1:Agricultural (wheat grain production)**

**S2: Refinery (ethanol production)**

**S3: Gasoline production (fossil fuel production)**

**S4: Final Fuel use (ethanol and gasoline blend+ combustion in a FFVehicle)**

## LCA
## Inventory Analisys

### Data Sources :

- **Questionnaires compiled by italian farmers**
- **Questionnaires compiled by the northern Italy real scale plant designers**
- **Consultation of italian database (ISTAT, ENAMA) and Simparo database (Ecoinvent, ETH-ESU)**
- **Scientific Literature**

| | Data from literature | Field data |
|---|---|---|
| **Agricultural phase** | | |
| Farming techniques | | farmers questionnaires |
| Specific production | Istat, 2007; CeSPra, 2004 | farmers questionnaires |
| Fertilizers/chemical products | Regione Lombardia,2007; Regione Umbria, 2004; | farmers questionnaires |
| Diesel | ENAMA, 2007; DM 26/2/2007; Dones et al., 2004 | farmers questionnaires |
| Tractors and machinery | Nemecek et al., 2004 | farmers questionnaires |
| Seeds | Nemecek et al., 2004; Regione Veneto, 2003 | |
| Transport | Spielmann et al., 2004 | |
| **Refinery phase** | | |
| Plant design and structure | | Triera company questionnaire |
| Specific production | | Triera company questionnaire |
| Chimical reagents | Bernesson et al, 2006; Althaus et al., 2004; ETH-ESU, | |
| Steam | Airfeen et al, 2007; Dones et al., 2004 | |
| Electricity | BUR n°92, 2007; Dones et al. 2004 | |
| **Use phase** | | |
| Fuels characteristics | Lechón et al, 2005; Martini et al, 2007 | |
| Low sulphur petrol | ETH-ESU, 1996 | |
| **Transport** | | |
| Farm-plant | Bernesson et al, 2006; Spielmann et al., 2004 | Italian maps |
| Plant-gasoline station | Ecoinvent, 2006; Spielmann et al., 2004 | |

## LCA
## Inventory Analisys

**SYSTEM FLOWS:**

**input and output from/to Nature/technosphere, for each subsystem**

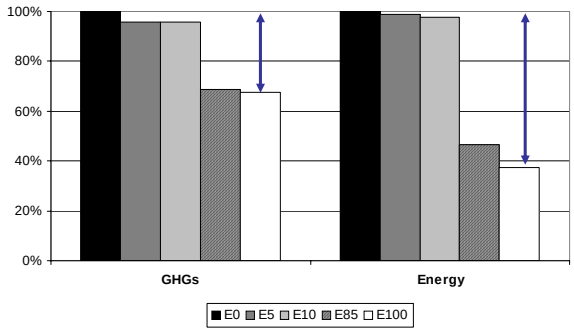
**Emissions to nature have been estimated through methodologies proposed in literature**

**Example: agricultural subsystem (UF 1 kg of grain)**

| | | |
|---|---|---|
| **Input from Technosphere** | | |
| Materials and fuels | | |
| 1. Diesel | 3,23E-02 | kg |
| 2. Urea | 2,54E-02 | kgN |
| 3. Triple superphosphate | 1,04E-02 | kg$P_2O_5$ |
| 4. Pesticide unspecified | 1,73E-04 | kg |
| 5. Seeds | 3,66E-02 | kg |
| 6. Tractors | 4,46 | kg |
| 7. Plough | 2,16 | kg |
| 8. Rotary Harrow | 3,29 | kg |
| 9. Fertilize spreader | 0,48 | kg |
| 10. Field sprayer | 0,24 | kg |
| 11. Sower | 0,97 | kg |
| 11. Harvester | 6,30 | kg |
| Transport | | |
| 1. Van | 5,52E-04 | tkm |
| 2. Barge | 2,69E-02 | tkm |
| 3. Rail | 3,57E-03 | tkm |
| 4. Lorry, 28t | 3,57E-03 | tkm |
| **Input from Nature** | | |
| 1. Arable soil, non irrigated | 1,75E-04 | ha |
| **Output to Technosphere** | | |
| Products | | |
| 1. Grain | 1 | kg |
| 2. Straw | 1 | kg |
| **Output to Nature** | | |
| Emissions to air | | |
| 1. $NH_3$ | 4,62E-03 | kg |
| 2. $N_2O$ | 8,51E-04 | kg |
| 3. $CO_2$ | 1,01E-01 | kg |
| 4. $CH_4$ | 4,18E-06 | kg |
| 5. CO | 2,10E-04 | kg |
| Emissions to water | | |
| 1. $NO_3$ | 5,23E-03 | kg |
| 2. P | 2,49E-04 | kg |

## LCA
## Impact Assessment

### Greenhouse gases (GHG) emissions and Energy Flow Indicator



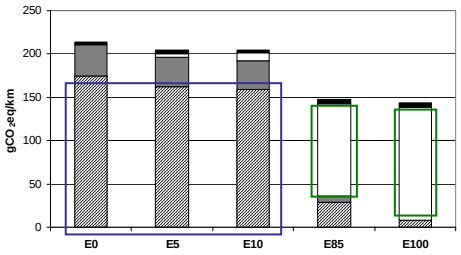

*Saves allowed*

| | GHG emissions gCO2eq/km | emissions saving % | Energy consumption MJ/km | Energy saving % |
|---|---|---|---|---|
| **E0** | 214 | | 3,09 | |
| E5 | 205,0 | 4,1 | 3,06 | 1,0 |
| E10 | 205,0 | 4,1 | 3,02 | 2,3 |
| E85 | 147 | 31,2 | 1,44 | 53,4 |
| **E100** | 144 | 32,6 | 1,16 | 62,5 |

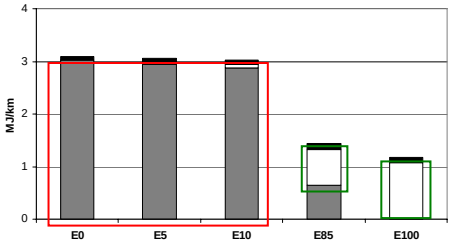
## LCA
## Impact Assessment

### Contribution Analysis for processes

*GHGs emissions*




*Energy flow*




Use

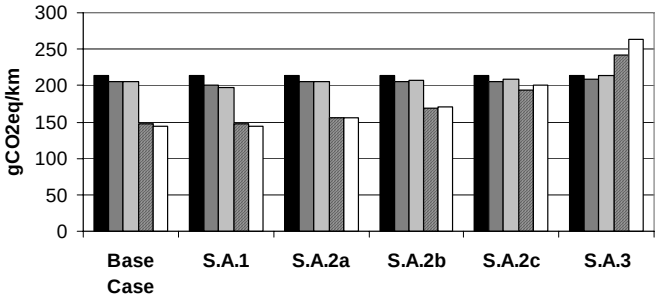
Gasoline production

Ethanol production

Blends transport

## LCA
## Results interpretation

### Sensitive Analysis

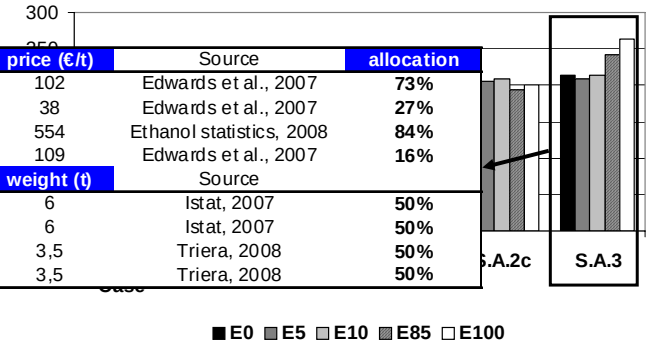



- **Base Case**: **specific consumption** (l/km) of blends linearly growing with ethanol content; **$N_2O$ emissions** equal to 1,25% of N applied; **allocation** of environmental charge on the mass value of by products;
- **S.A.1** **specific consumption** (l/km) assumed equal for low ethanol blends (E0, E5 and E10);
- **S.A. 2a/b/c**: **$N_2O$ emissions** equal to 2%-3%-5% of n applied like fertilizer;

## LCA
## Results interpretation

### Sensitive Analysis

| | price (€/t) | Source | allocation |
|---|---|---|---|
| Grain | 102 | Edwards et al., 2007 | 73% |
| Straw | 38 | Edwards et al., 2007 | 27% |
| Ethanol | 554 | Ethanol statistics, 2008 | 84% |
| DDGS | 109 | Edwards et al., 2007 | 16% |
| | **weight (t)** | Source | |
| Grain | 6 | Istat, 2007 | 50% |
| Straw | 6 | Istat, 2007 | 50% |
| Ethanol | 3,5 | Triera, 2008 | 50% |
| DDGS | 3,5 | Triera, 2008 | 50% |

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- **S.A.1 specific consumption (l/km) assumed equal for low ethanol blends (E0, E5 and E10);**
- **S.A. 2a/b/c: $N_2O$ emissions equal to 2%-3%-5% of N applied like fertilizer;**
- **S.A. 3: Allocation of environmental charge on the econimic value of by products**

## CONCLUSIONS

- **Bioethanol produced from wheat grain in Lombardy can be a good alternative at fossil gasoline**
- **On a LCA basis, pure bioethanol (E100) allows savings of GHGs emissions (-33%) and of Energy request (-62%) compared to fossil gasoline**
- **The LCA conduced results to be very sensitive to the allocation methodology. It would be prompt to enlarge the system boundaries to avoid the use of allocation**
- **Any alternative possible use of by products (STRAW and DDGS) hasen't been considered. To maximize the positive effects of the biofuel, possible alternative uses should be considered (energy recovery through combustion and use as animal food)**

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**Thank you for the attention**