Institut für Energetik und Umwelt

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- Energy
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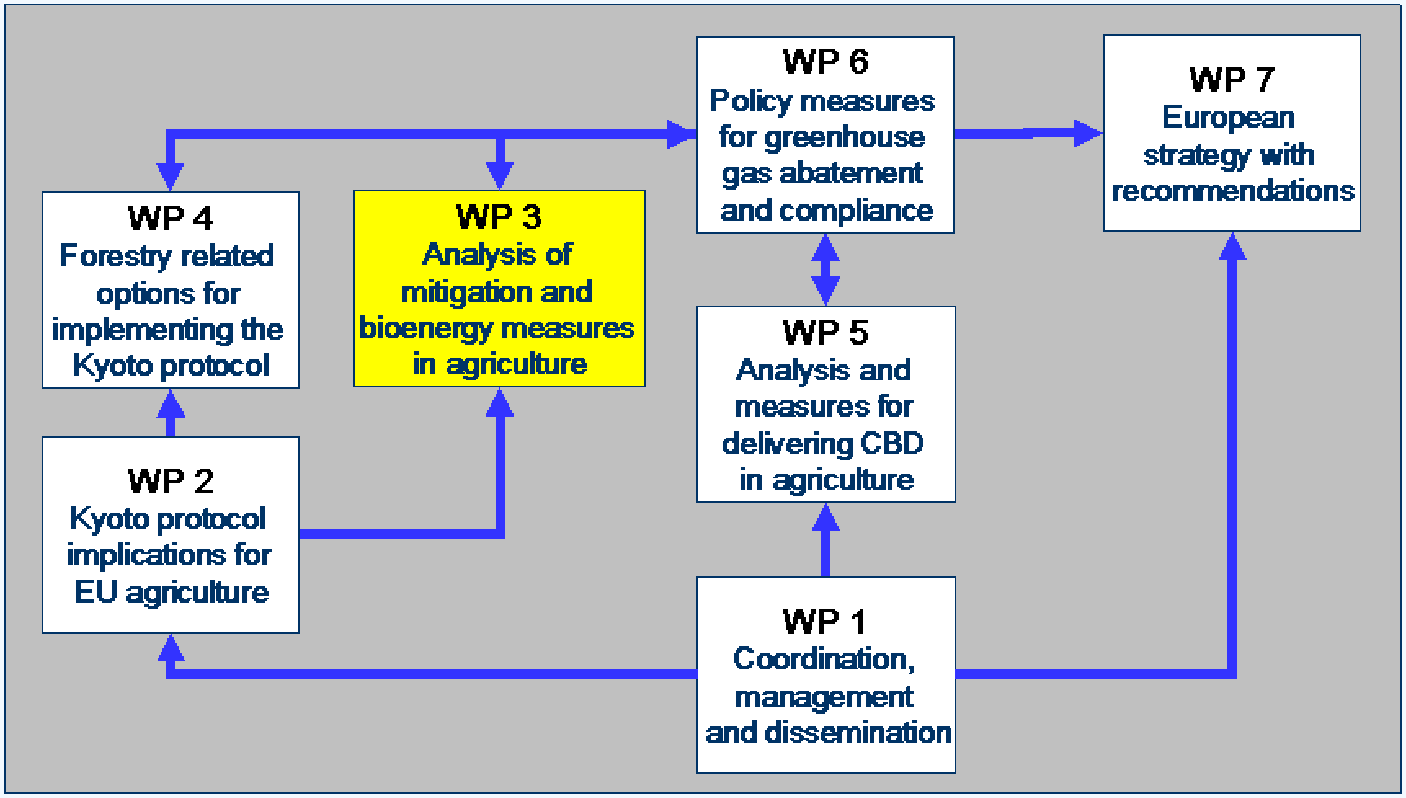
MEACAP
Impact of Environmental Agreements on the Common Agricultural Policy

# WP3 – Analysis of mitigation and bioenergy measures in agriculture



# WP3 – Analysis of mitigation and bioenergy measures in agriculture

## The work in WP3 is divided into two tasks:

**A.** Measures within the agricultural sector that could reduce GHG emissions

**B.** The production of renewable energy sources from agriculture

# WP3 Objectives / Deliverables

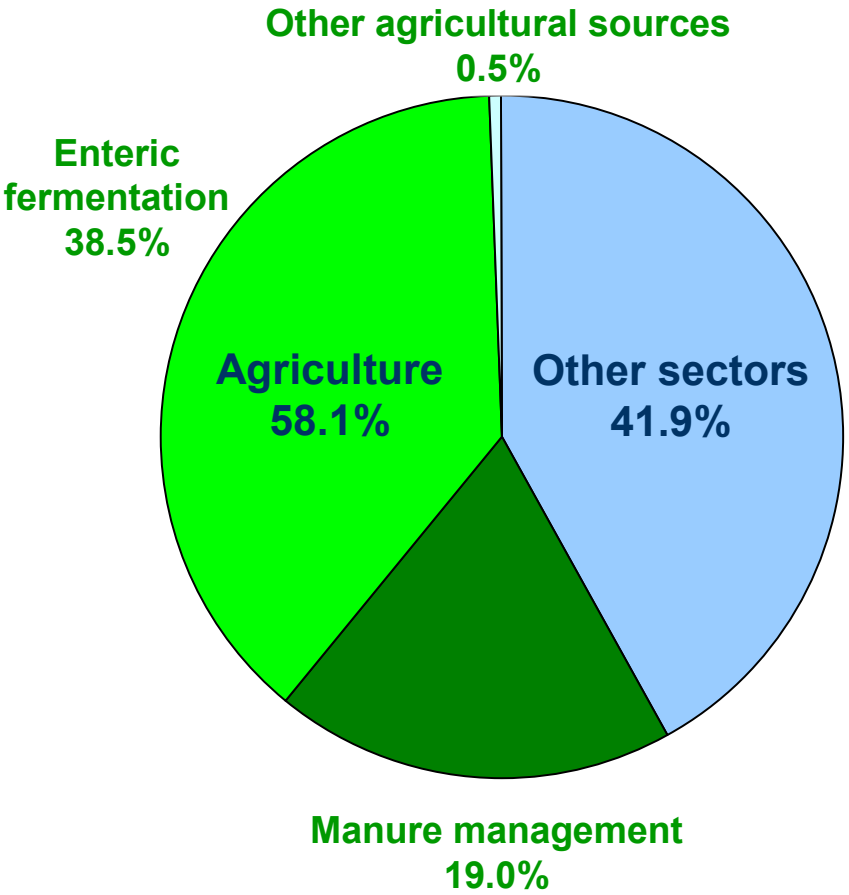
**D7(a/b):** Report on surveys of GHG mitigation options to reduce GHG emissions in the agricultural sector and bioenergy production chains

**D10(a/b):** Report describing the GHG mitigation potential, abatement costs and technical feasibility of mitigation options and bioenergy production chains

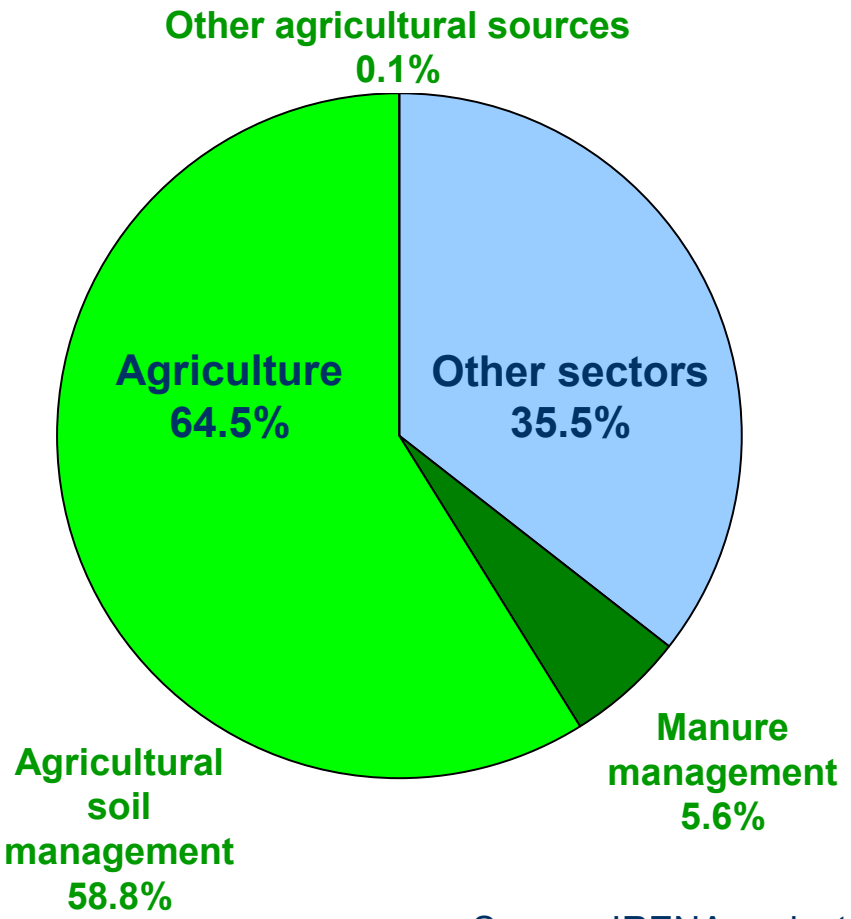
**D15(a/b):** Detailed integrated cost-benefit analysis of GHG mitigation options and bioenergy production chains

# A. Share of $CH_4$ and $N_2O$ emissions (EU15)

## $CH_4$

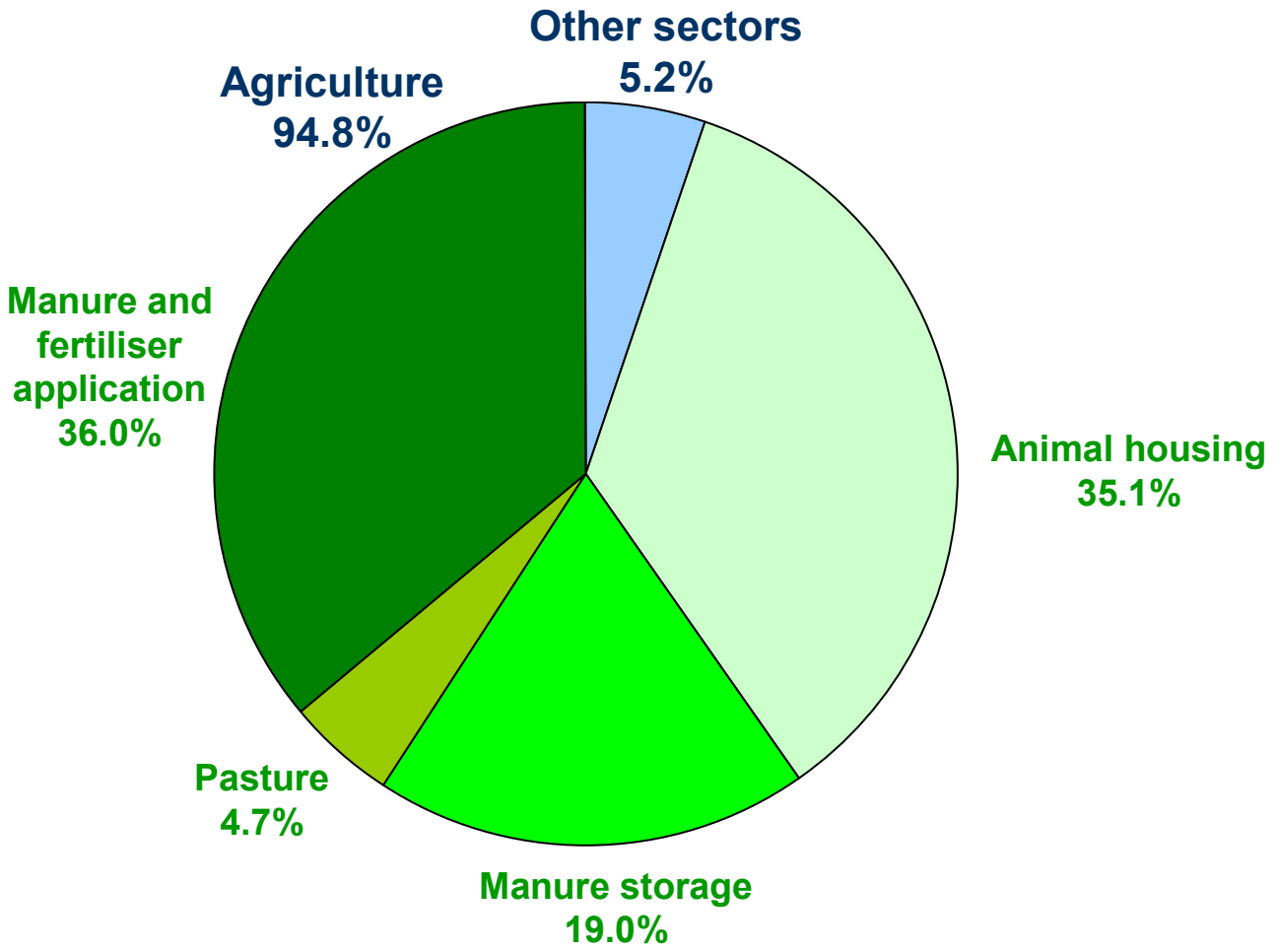



## $N_2O$




Source: IRENA project

# Share of $NH_3$ emissions (Germany)



# Technical and management-based mitigation measures in agriculture (D7a)

1. **Measures related to livestock and poultry farming**
   - Animal housing and in-barn manure management
   - Grassland and grazing management
   - Feeding strategies
   - Outdoor manure management (storage techniques)
2. **Measures on crop production**
   - Slurry, manure and fertiliser management
   - Manure application techniques
   - Carbon sequestration
3. **Management-based measures**
   - Extensification / Intensification and livestock density
   - Grazing in comparison to animal housing
   - Anaerobic digestion
4. **Reduction of use of fossil fuels**
5. **(Political instruments)**

# Selection and evaluation of mitigation measures in agriculture

Three step screening and evaluation process of measures:

**1.**

| GHG mitigation potential | Technical feasibility | Environmental added value | Cost effectiveness |
|---|---|---|---|
| ↑ ↗ → ↘ ↓ | ↑ ↗ → ↘ ↓ | ↑ ↗ → ↘ ↓ | ↑ ↗ → ↘ ↓ |

**2.**

| GHG mitigation potential | Technical feasibility | Environ-mental added value | Cost effective-ness | Social acceptance | Animal health and welfare / ethical acceptance | State of technology knowledge | Availability of emission factors |
|---|---|---|---|---|---|---|---|
| **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** | **0/1/2/3/4/5** |

Selection of appropriate measures ➲ 0 = 'killing assumption'

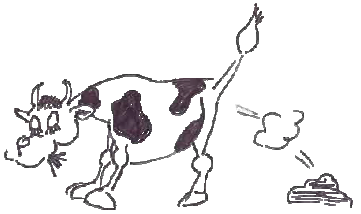
Detailed description of selected mitigation measures (EF, costs etc.)

**3.** - Complete and detailed description of mitigation measures
- Emission factors, costs, feasibility etc.
- Cost-benefit analysis

# Technical and management-based GHG mitigation measures selected for modelling (1)

## 1. Feeding strategies

- to reduce N losses by low nitrogen feed and by increase of feed N efficiency (cattle)
- (multi)phase feeding / with the addition of (synthetic) amino acids (pigs)

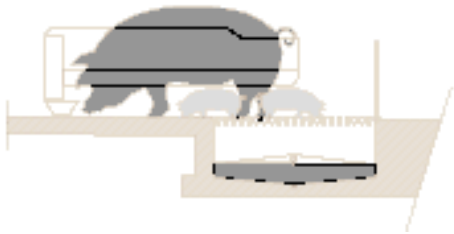


## 2. Comparison of straw- and slurry-based housing systems

- tied ↔ loose housing systems
- slurry- ↔ straw-based (deep litter) housing systems

## 3. Frequency of manure removal

- change in the frequency of manure removal
- use of improved manure removal techniques



# Technical and management-based GHG mitigation measures selected for modelling (2)

## 4. Improved manure storage techniques (cover techniques)

**Average mitigation of $NH_3$ emissions of different storage cover techniques in % compared to an uncovered slurry tank without natural crust.**

| Cover technique | Cattle slurry | Pig slurry |
|---|---|---|
| Natural crust | 70 (30-80) | 30 (20-70) |
| Straw | 80 (70-90) | 80 (70-90) |
| Granulates | 85 (80-90) | 85 (80-90) |
| Plastic sheeting | 85 (80-90) | 85 (80-90) |
| Rigid cover | 90 (85-95) | 90 (85-95) |

## 5. Manure application techniques

- broadcasting ↔ trail hose / trail shoe / injection
- the modelling will base on equations developed within the EU projects ALFAM and MIDAIR

## 6. Slow- and controlled-release fertilisers and fertilisers with urease or nitrification inhibitors

- reduction of $N_2O$ emissions by ~50% (with nitrification inhibitors)

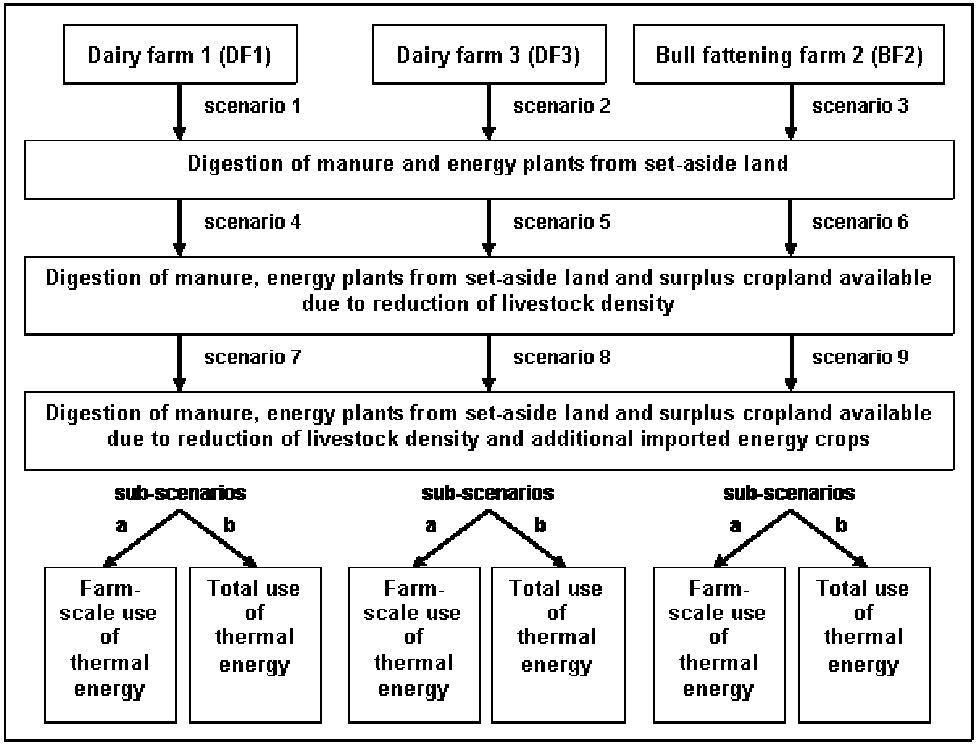
# Technical and management-based GHG mitigation measures selected for modelling (3)

## 7. Increase of grazing in comparison to animal housing

- impact on $NH_3$ and $N_2O$ emissions from pastures compared to emissions from animal houses and manure application

## 8. Anaerobic digestion

- impact on $CH_4$, $N_2O$ and $NH_3$ due to changed manure management
- substitution of fossil fuels dependent on input quantity and quality and the amount of used electricity and thermal energy



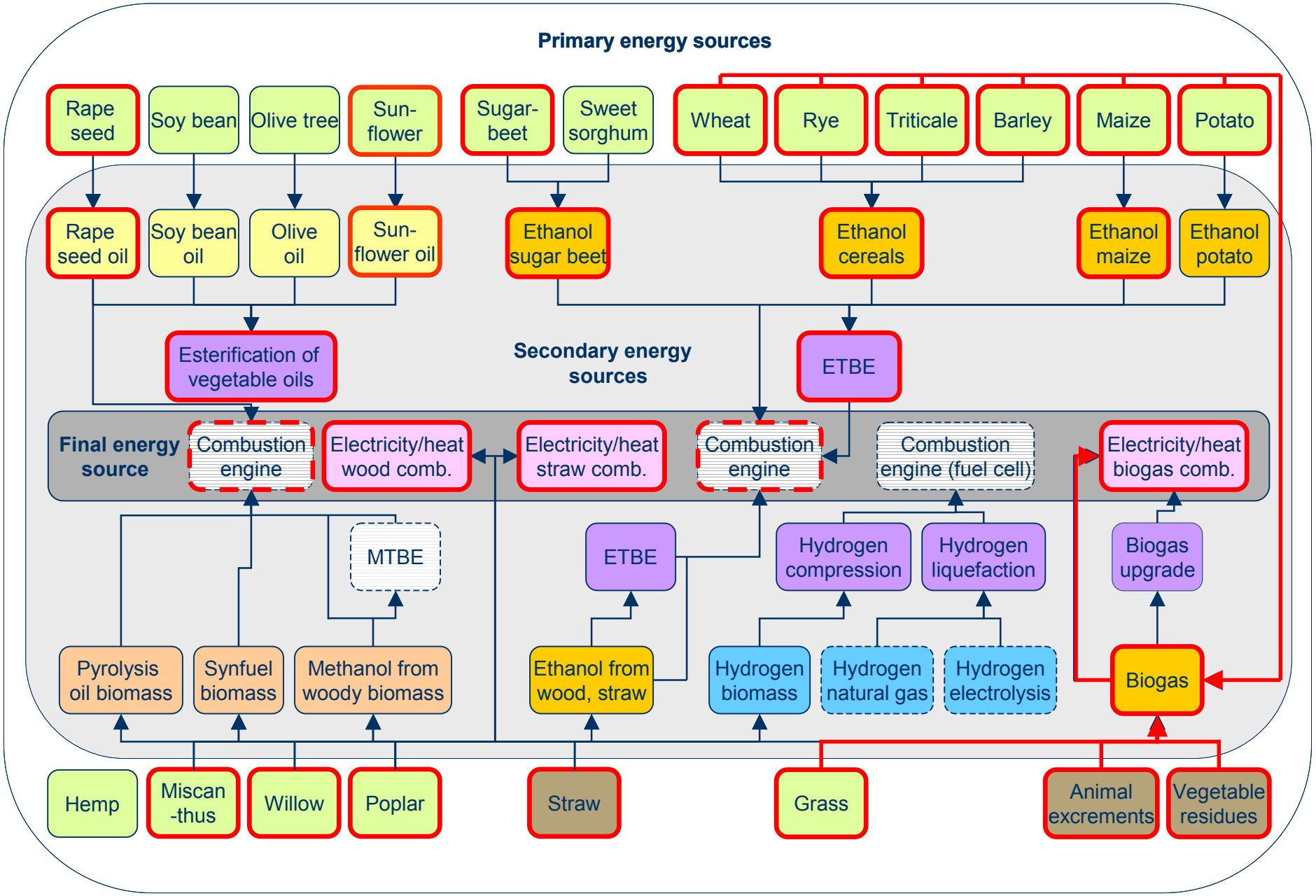

## 9. Organic farming

# WP3 – Analysis of mitigation and bioenergy measures in agriculture

**A.** Measures within the agricultural sector that could reduce GHG emissions

**B.** The production of renewable energy sources from agriculture

# Bioenergy production chains



# Esterification of rape seed oil (1)

| | | | | | |
|---|---|---|---|---|---|
| **Biomass production:** | **plantation of rape seed, annual plant** | | | | |
| **Input parameters:** | | Amount | | Specific costs | |
| Land | | 1 | ha | 100 - 400 | €/ha |
| Seeds | | 3,3 | kg/ha | 11 | €/kg |
| Fertilisers: | Nitrogen | 129 | kg/ha | 0,81 | €/kg |
| | Phosphorus | 54 | kg/ha | 0,68 | €/kg |
| | Potassium | 30 | kg/ha | 0,39 | €/kg |
| | Lime | 300 | kg/ha | 0,06 | €/kg |
| Weed control | | 3,5 | l AI/ha* | 103 | €/ha |
| Machinery | | 7,1 | Akh/ha | 245 | €/ha** |
| Manpower** | | 7,1 | Akh/ha | 17 | €/Akh |
| Insurance | | | | 13,7 | €/$t_{dm\ output}$ |
| Other services*** | | 305 | MJ/$t_{dm\ output}$ | 10 | €/$t_{dm\ output}$ |
| Fuel | | 84 | l/ha | 0.5 - 0.6 | €/l |
| **Output parameters:** | | | | | |
| Rape seed | | 3,5 | $t_{dm}$/ha | 3,8 | $t_{(fm9\%)}$/ha***** |
| By-product | Rape straw | 10-12 | $t_{dm}$/ha | averages in Germany (1997-2004) | |
| **Costs:** | | | | | |
| Land (average germany) | | 175 | €/ha | | |
| Process | Input products | 314 | €/ha | | |
| | Maschinery, labour | 245 | €/ha | | |
| | Other services + Insurance | 83 | €/ha | | |
| **Total of costs:** | | **817** | €/ha | | |
| Revenues from by-products | | -115 | €/ha | 11,5 | €/$t_{by\text{-}product}$ |
| | | **702** | €/ha | 201 | €/$t_{dm}$ |

8,4274 €/GJ

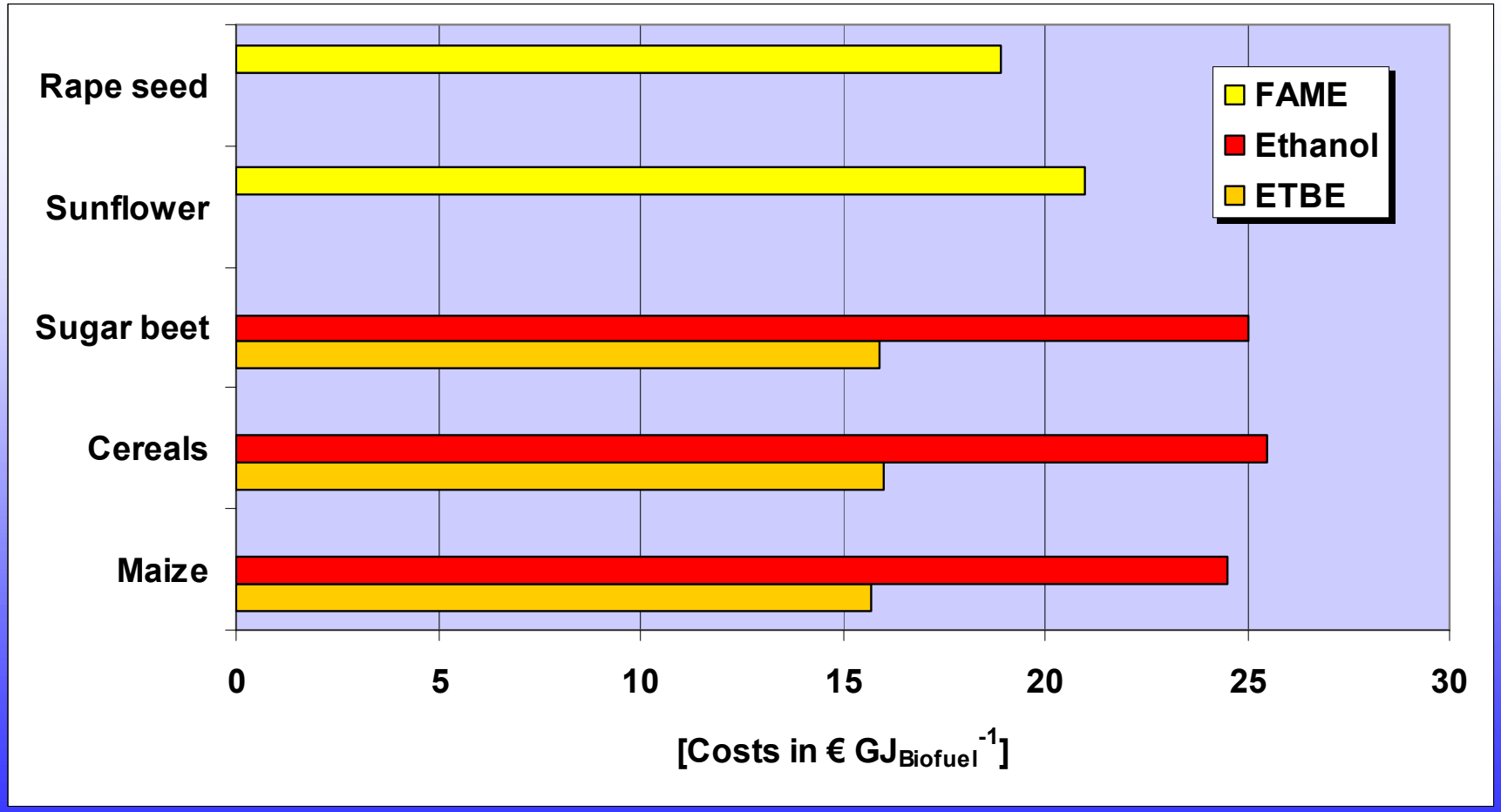
| | | | | | |
|---|---|---|---|---|---|
| **Transportation:** | **by train, truck and vessel** | | | | |
| train | | 2,52 | tkm/$GJ_{Rape}$ | | |
| truck | | 2,52 | tkm/$GJ_{Rape}$ | | |
| vessel | | 11,8 | tkm/$GJ_{Rape}$ | | |
| **Costs:** | | | | **1,6** | €/$t_{dm}$ |

*l AI/ha: liters of active ingredient per hectare
**includes costs of manpower and fuel
***drying, cleaning of seeds
****mill and esterification
*****fm fresh matter (water content %)

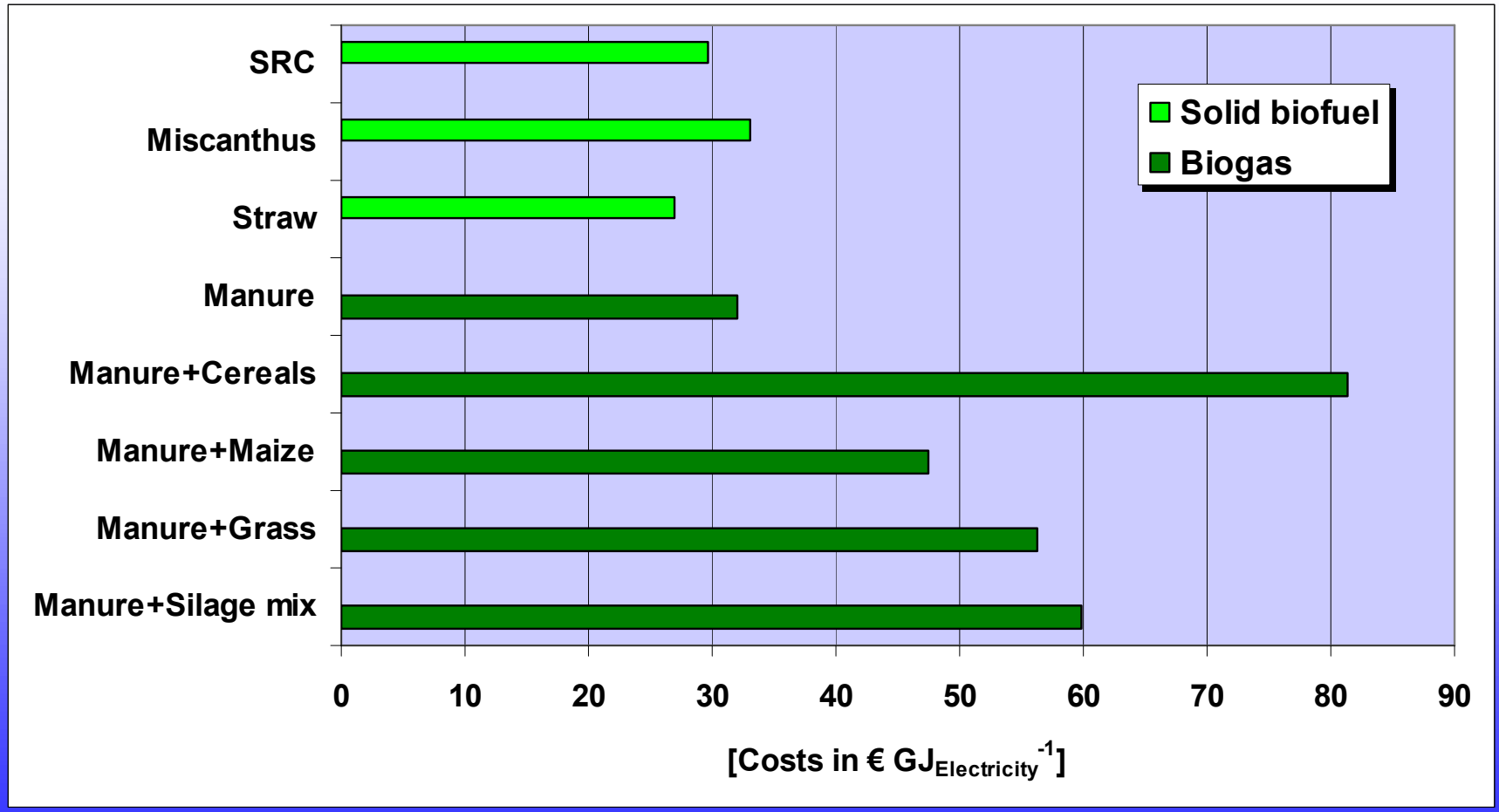
# Esterification of rape seed oil (2)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Conversion process 1:** | oil mill | | | | | | |
| **Input parameters:** | | Amount | | Energy | | heat values | |
| Rape seed | (water content 9%) | 1 | t | 23,8 | GJ | 23,8 | GJ/t: |
| Electricity | | | | 0,24 | GJ | | |
| Natural gas | | | | 0,45 | GJ | | |
| **Output parameters:** | | | | | | | |
| Rape seed oil | | 0,38 | t | 14,28 | GJ | 37,6 | GJ/t |
| By-product | coarse colza meal | 0,57 | t | 9,52 | GJ | 16,6 | GJ/t |
| Conversion factor[1] | ($output_{main\ product}$/input) | 0,38 | t/t | 0,6 | GJ/GJ | | |
| **Conversion process 2:** | esterification | | | | | | |
| **Input parameters:** | | | | | | | |
| Rape seed oil | | 379,8 | kg | 14,28 | GJ | 37,6 | GJ/t |
| Methanol | | 41,4 | kg | 1,58 | GJ | 38,08 | GJ/t |
| Acids | | 0,4 | kg | 0,006 | GJ | 15 | GJ/t |
| NaOH | | 2,4 | kg | 0,048 | GJ | 19,87 | GJ/t |
| Electricity | | | | 0,069 | GJ | | |
| Natural gas | | | | 0,625 | GJ | | |
| Light fuel oil | | | | 0,050 | GJ | | |
| Infrastructure**** | | 3,6 | €/$GJ_{Biodiesel}$ | | | | |
| **Output parameters:** | | | | | | | |
| Biodiesel | | 376,0 | kg | 13,99 | GJ | 37,2 | GJ/t: |
| Glycerol | | 37,6 | kg | 0,50 | GJ | 13,2 | GJ/t: |
| Conversion factor[2] | ($output_{main\ product}$/input) | 0,99 | t/t | 0,98 | GJ/GJ | | |
| Conversion factor[1+2] | ($output_{main\ product}$/input) | 0,38 | t/t | 0,59 | GJ/GJ | | |
| **Costs:** | | | | | | | |
| Biomass | | 184 | €/$t_{Input}$ | | | | |
| Process | | 220 | €/$t_{Input}$ | | | | |
| Revenues from by-products | | -140 | €/$t_{Input}$ | 245 | €/$t_{by\text{-}product}$ | | |
| **Total of costs** | (at gate conversion plant) | **701,7** | **€/$t_{Biofuel}$** | 18,9 | €/$GJ_{Biofuel}$ | 37,2 | GJ/t: |

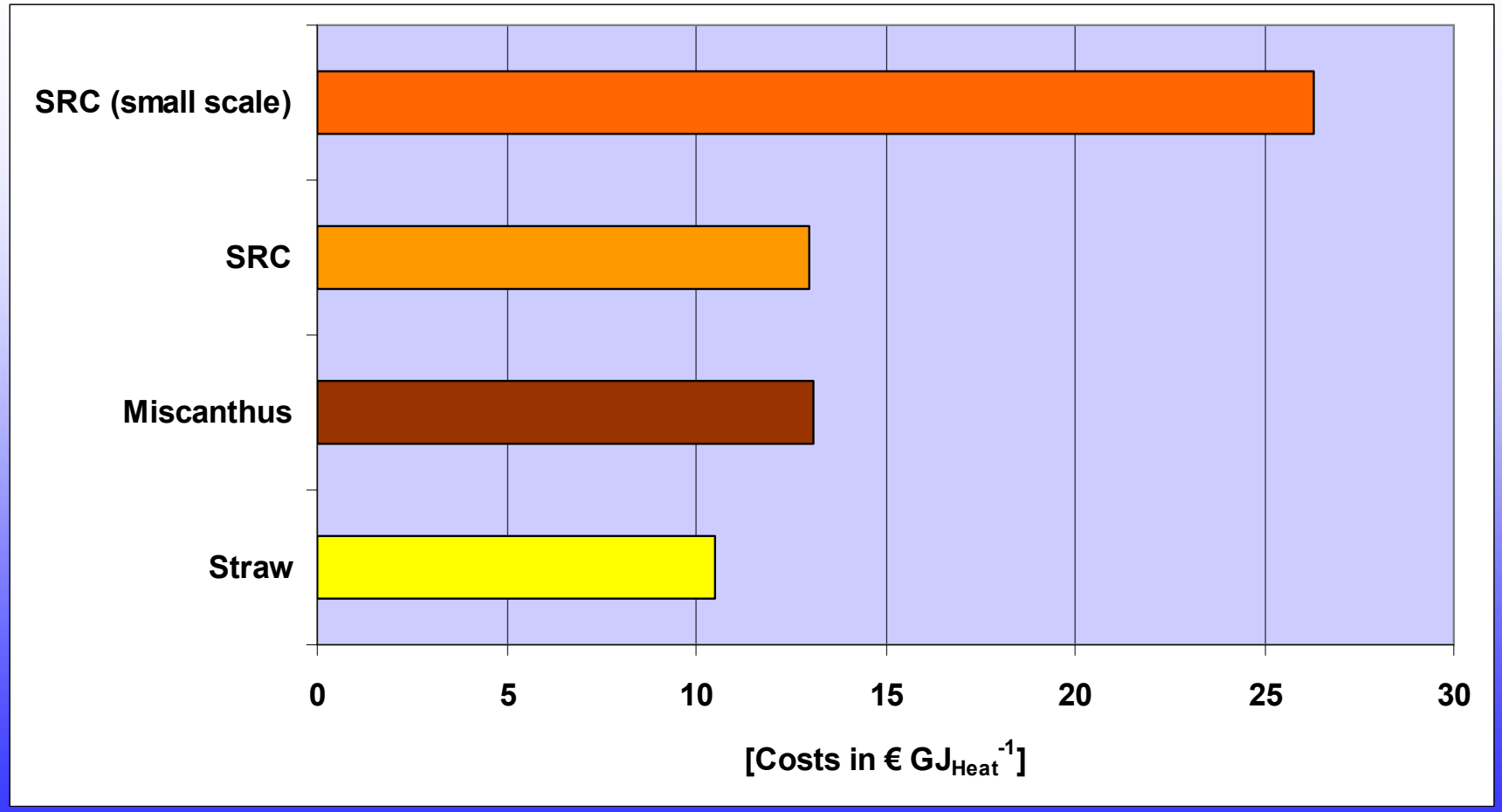
# Economic performance for the provisions of (automotive) biofuels



# Economic performance for the provisions of electricity



# Economic performance for the provisions of heat

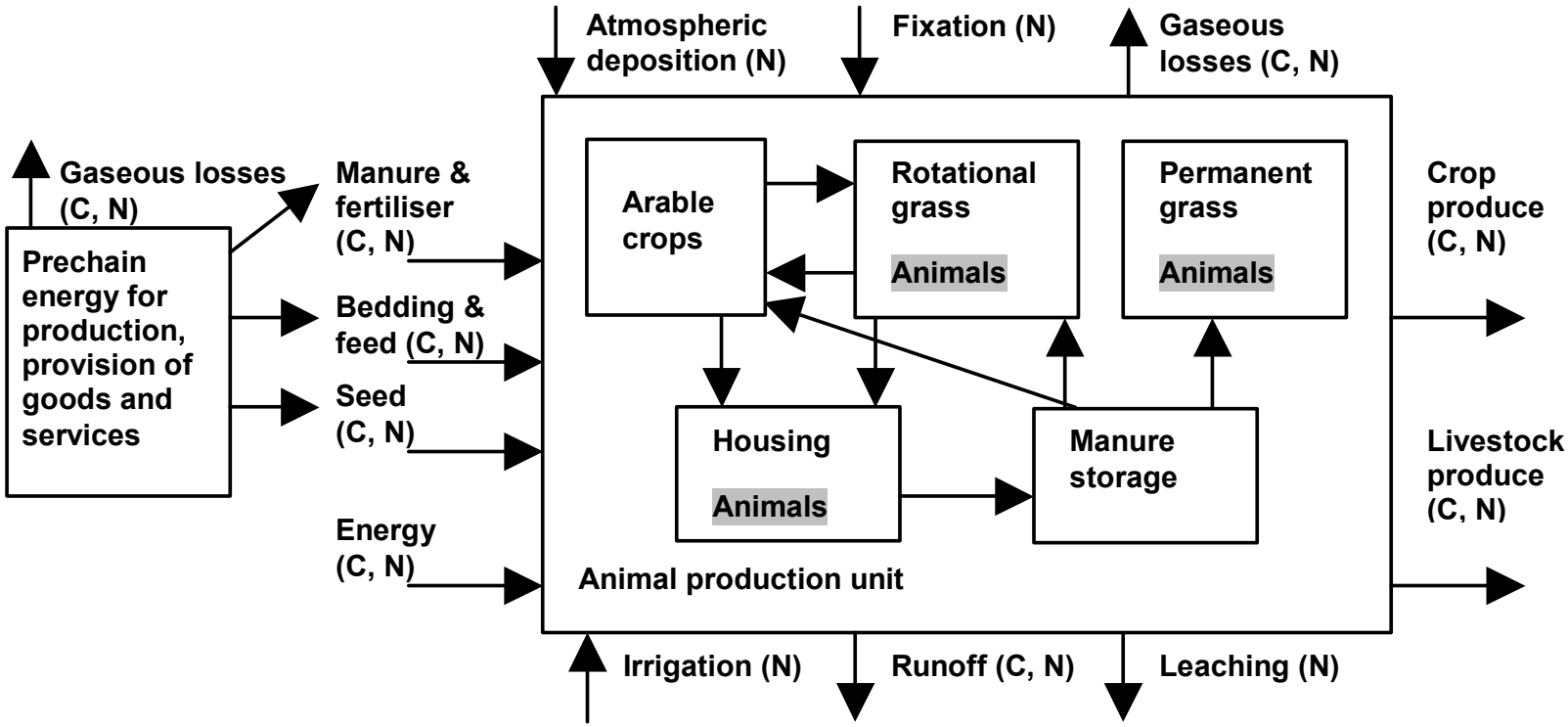


# Conclusions

- There are many technical and management-based measures within the entire agricultural production sector with high GHG mitigation potential which have to be modelled on whole farm level.
- There are various bioenergy production chains and different renewable final energy sources from agricultural production (fuels, electricity, heat) that are economically competitive.

**Thank you for your attention!**

# Model farm system



# Selection of technical measures

| Evaluation according to the following criteria: |
|---|
| GHG mitigation potential |
| Technical feasibility |
| Environmental added value |
| Cost effectiveness |
| Social acceptance (by producers and consumers) |
| Animal health and welfare / ethical acceptance |
| State of technology knowledge (of farmers and science) |
| Availability of emission factors (EF) |
| 5 = very good to 1 = very bad, 0 = killing assumption |

| | General criteria: |
|---|---|
| 1 | N efficiency |
| 2 | Animal efficiency, livestock density |
| 3 | Manure |
| 4 | Carbon sequestration |
| 5 | Biomass |
| 6 | Agricultural energy use |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | weighting factor | | | | | | | | | |
| | | | | | | | | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | | |
| General criteria | | | Chapter number | Chapter title | Relevant GHG | Relevant GHG | Relevant GHG | Relevant GHG | GHG mitigation potential | Technical feasibility | Environmental added value | Cost effectiveness | Social acceptance | Animal health and welfare / ethical acceptance | State of technology knowledge | Availability of emission factors (EF) | TOTAL | Comments |
| 1 | 3 | 6 | 2.9.3 | Adapation of fertilisation and pesticide application on demand | N | $N_2O$ | $NH_3$ | GHG | 5 | 5 | 4 | 5 | 4 | 4 | 4 | 3 | 54 | is already part of good farming practice |
| 1 | 3 | | 2.10.3 | Incorporation of applied manure and / or slurry into soil | $NH_3$ | $N_2O$ | GHG | $CH_4$ | 5 | 5 | 3 | 4 | 5 | 4 | 5 | 4 | 54 | additional operation needed; may increase $N_2O$ emissions |
| 1 | 3 | 6 | 1.3.2 | Adaptation of fertilisation on demand | GHG | | | | 5 | 5 | 4 | 5 | 4 | 4 | 4 | 3 | 54 | |
| 3 | 1 | | 1.5.5 | Reducing the surface per unit volume of slurry or FYM stores | $NH_3$ | $CH_4$ | $N_2O$ | GHG | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 53 | see also tanks instead of lagoons (1.5.13.2) |
| 3 | 1 | | 1.5.13.3 | Natural crust | $NH_3$ | $CH_4$ | $N_2O$ | | 4 | 5 | 3 | 5 | 5 | 4 | 5 | 4 | 53 | $N_2O$ emissions may increase |
| 5 | 4 | | 2.12.1 | Combustion of energy crops | $CO_2$ | GHG | | | 5 | 4 | 4 | 4 | 5 | 3 | 5 | 4 | 52 | |
| 3 | 1 | 6 | 1.5.13.4.2 | Flexible plastic cover | $NH_3$ | $CH_4$ | $N_2O$ | GHG | 5 | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 51 | too expensive for lagoons |
| 1 | 6 | | 2.8 | Use of N fixing crops | $N_2O$ | GHG | $NH_3$ | | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 2 | 51 | lack of country data on N fixing crops |