WP6
Environmental Impact Assessment
and
Life Cycle Analysis of kenaf production and use

Partners

UniNOVA, Portugal (7)

INRA, France (11)

Start month: 12th – 1st March 2004

End month: 39th – 31st May 2006

Ecological criteria to be considered

- Net avoided use of fossil energy
- Net avoided emission of greenhouse gases
- Net emission of acidifying gases
- Emission of ozone depleting gases
- Emission of nitrogen and other nutrients/minerals to soil and water
- Emission of pesticides
- Erosion
- Groundwater depletion
- Use of resources
- Waste production and utilisation

Net avoided use of fossil energy

Net Energy Gain = **Energy Output** - **Energy Input**

Energy Output

- **Productivity x Heat of Combustion**
  - **When Kenaf is used for energy purposes**
- **Energy needed to produce a substitute of a possible Kenaf product**
  - **When Kenaf is used for other purposes**

Energy Input

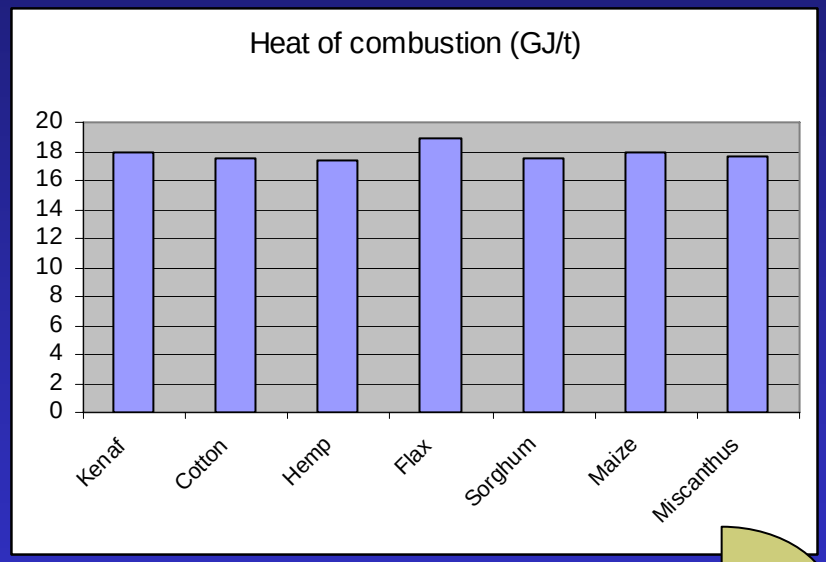
- **Production of Seeds**
  Fertilisers
  Pesticides
- **Machinery**

Energy production

Energy output

Heat of Combustion

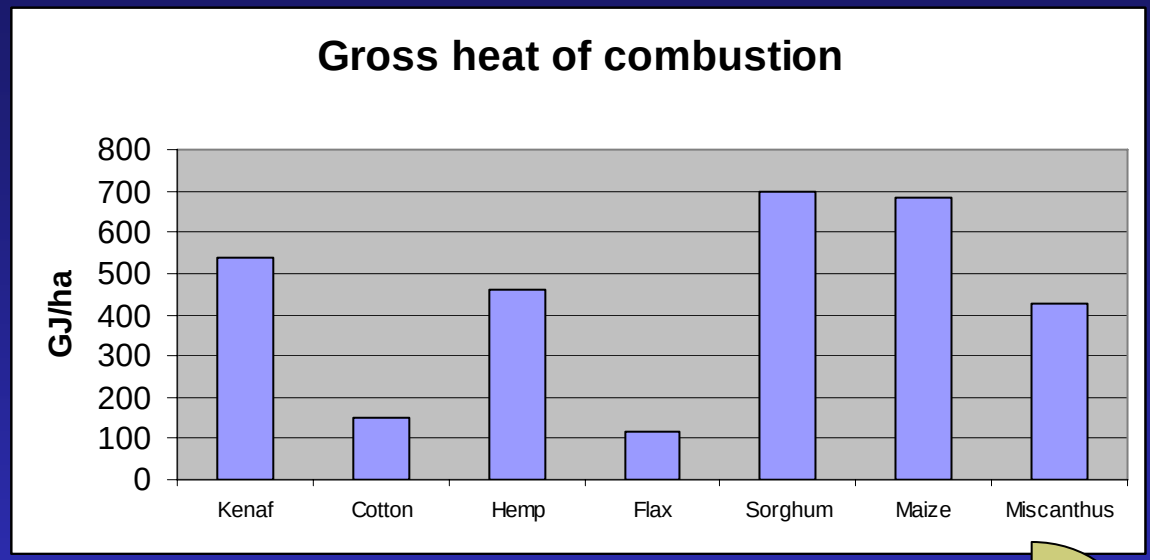
Kenaf	17.3 – 18.6 GJ.t^{-1}
Cotton	15.8 – 19.1 GJ.t^{-1}
Hemp	16.8 – 17.9 GJ.t^{-1}
Flax	18.2 – 19.5 GJ.t^{-1}
Sorghum	16.9 – 18.0 GJ.t^{-1}
Maize	17.3 – 18.5 GJ.t^{-1}
Miscanthus	16.4 – 18.9 GJ.t^{-1}



No significative differences

Productivity in Southern Europe

Kenaf	- 30.0 t.ha^{-1}
Cotton	- 8.7 t.ha^{-1}
Hemp	- 26.4 t.ha^{-1}
Flax	- 6.2 t.ha^{-1}
Sorghum	- 40.0 t.ha^{-1}
Maize	- 38.2 t.ha^{-1}
Miscanthus	- 24.0 t.ha^{-1}



Per region there are differences in crop yields, which lead to differences in energy output, but we do not assume differences in conversion efficiences

Sorghum > Maize > Kenaf > Hemp > Miscanthus > Cotton > Flax

Energy Inputs

Production phase:

- production of seed and plant-cuttings
- production of chemical fertilizer
- production of pesticides
- production and use of machinery in crop cultivation
- irrigation
- chipping of biomass
- drying and storage of biomass at the farm

Pre-conversion phase

- transport of biomass
- drying and storage of biomass at the plant

Conversion phase

- process energy needed for conversion

	-production of seed and plant-cuttings	- machine use, irrigation and chipping
Kenaf	- 0.48 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Cotton	- 0.53 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Hemp	- 1.6 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Flax	- 1.41 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Sorghum	- 1.0 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Maize	- 0.1 GJ.ha^{-1}	14.2 GJ.ha^{-1}
Miscanthus	- 1.6 GJ.ha^{-1}	14.3 GJ.ha^{-1}

production of chemical fertilizers and pesticides

N-fertilizer = 38.6 MJ.kg^{-1}, P-fertilizer = 7.6 MJ.kg^{-1}, K-fertilizer = 3 MJ.kg^{-1}, Pesticides = 51.5 MJ.kg^{-1} of active ingredient

	N	P	K	Pesticides	Total
Kenaf	3.1	0.20	0.30	0.049	3.6 GJ.ha^{-1}
Cotton	2.1	0.12	0.29	0.70	3.2 GJ.ha^{-1}
Hemp	3.1	0.54	0.41	0.052	4.1 GJ.ha^{-1}
Flax	1.4	0.43	0.23	0.088	2.2 GJ.ha^{-1}
Sorghum	3.5	0.24	0.35	0.082	4.1 GJ.ha^{-1}
Maize	5.2	0.21	0.39	0.11	5.9 GJ.ha^{-1}
Miscanthus	1.9	0.07	0.11	0.015	2.1 GJ.ha^{-1}

Drying and storage of biomass

2.26 GJ/t water evaporated, at the plant

	dry matter at harvest	
Kenaf	30%	147 GJ.ha^{-1}
Cotton	85% - ok	0.0 GJ.ha^{-1}
Hemp	85% - ok	0.0 GJ.ha^{-1}
Flax	70%, can dry to 85% at the farm	0.0 GJ.ha^{-1}
Sorghum	50% (not necessary to dry)	0.0 GJ.ha^{-1}
Maize	30%	186 GJ.ha^{-1}
Miscanthus	70%, can dry to 85% at the farm	0.0 GJ.ha^{-1}

Transport of biomass

0.0008 GJ/ t fresh biomass/ km

plant at a maximum distance of 30 km, trucks return empty

Kenaf	**2.4 GJ.ha^{-1}**
Cotton	**0.27 GJ.ha^{-1}**
Hemp	**0.77 GJ.ha^{-1}**
Flax	**0.20 GJ.ha^{-1}**
Sorghum	**1.9 GJ.ha^{-1}**
Maize	**3.1 GJ.ha^{-1}**
Miscanthus	**0.70 GJ.ha^{-1}**

Higher the moisture and the productivity

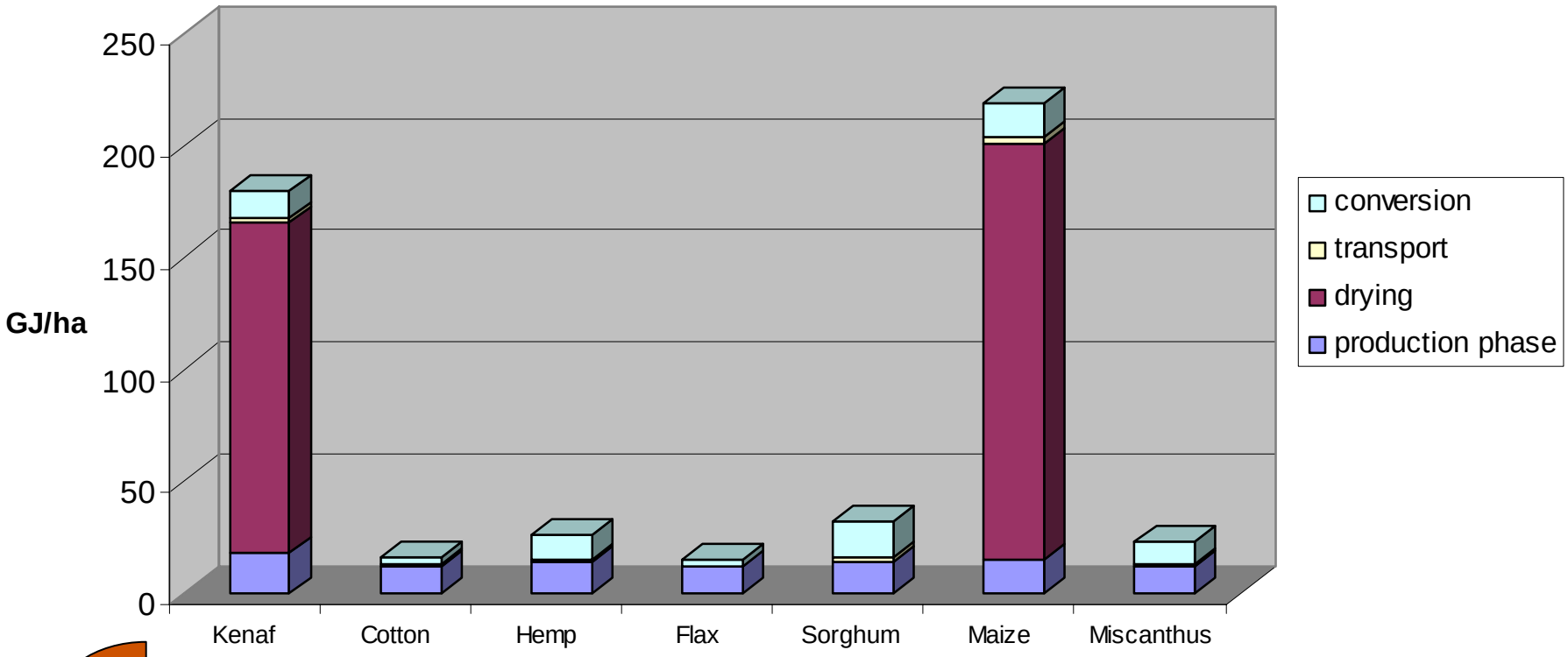
Higher the energy costs of transportation

Conversion phase

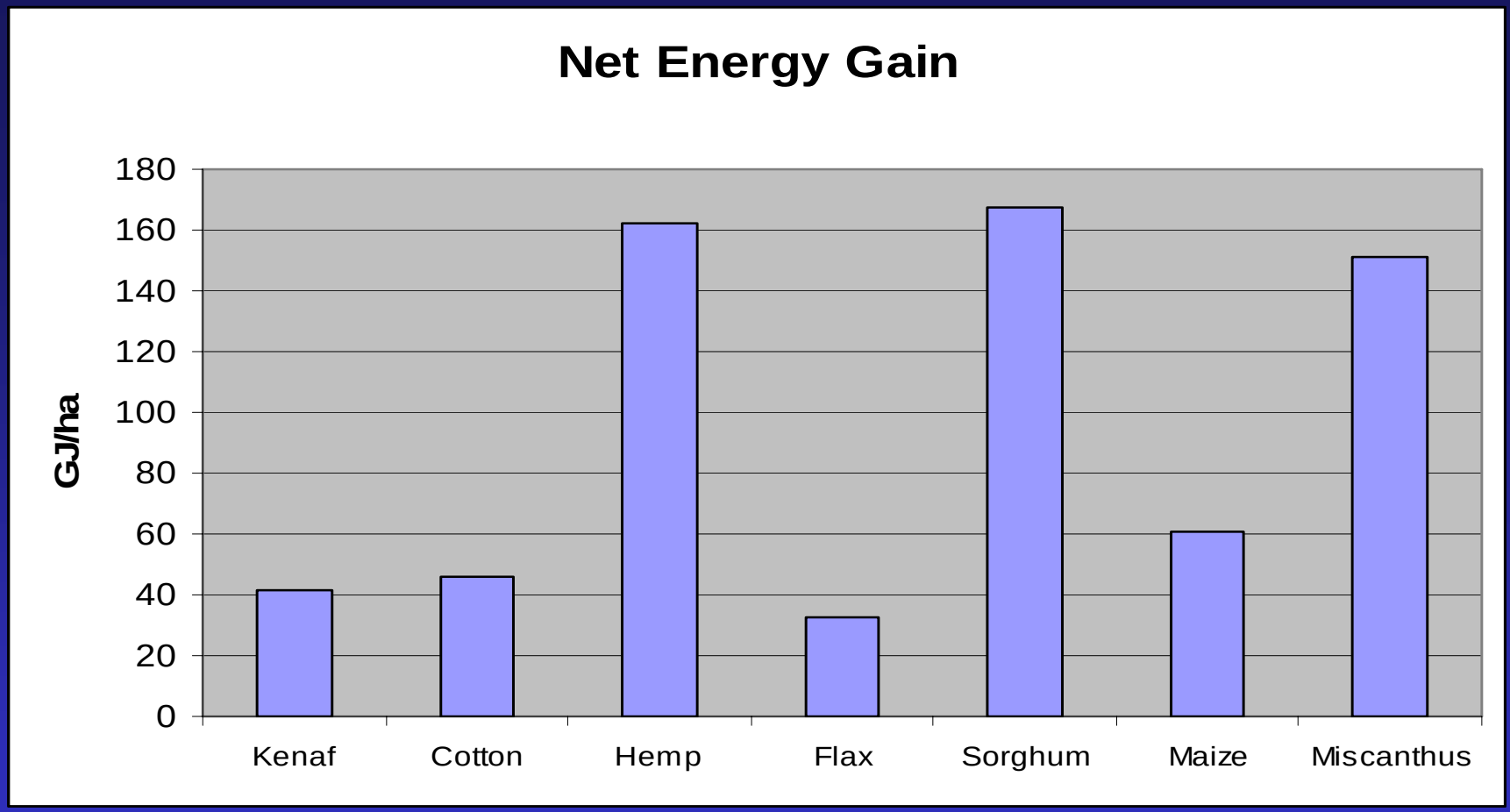
(gasification 50 MWe, 0.40 GJ/t, to produce electricity and heat, Distillation + CHP, 0.28 GJ/t, to produce electricity and heat, na 0.58 GJ/t, to produce transport fuel

	route	
Kenaf	gasification 50 MWe	12 $GJ.ha^{-1}$
Cotton	gasification 50 MWe	3.5 $GJ.ha^{-1}$
Hemp	gasification 50 MWe	11 $GJ.ha^{-1}$
Flax	gasification 50 MWe	2.5 $GJ.ha^{-1}$
Sorghum	distillation + CHP	17 $GJ.ha^{-1}$
Maize	gasification 50 MWe	15.3 $GJ.ha^{-1}$
Miscanthus	gasification 50 MWe	9.6 $GJ.ha^{-1}$

Energy inputs



Drying can be costly in terms if energy inputs



Considering the following net electric efficiencies:

CHP 5 MWe – 27.5%; gasification 50 MWe – 40.9%; ethanol production – 29.5%

Sorghum > Hemp > Miscanthus > Maize > Cotton > Kenaf > Flax

All crops presented positive energy balances