Life cycle assessment of hemp fibre production and hemp products in Europe - including comparison to other natural fibres

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Agenda

1) Introduction to life cycle assessment (LCA)
2) Results of recent LCAs for hemp fibre production
3) Discussion of critical aspects
4) Literature review – Hemp vs. natural and synthetic fibres and insulation materials

1) Introduction to life cycle assessment (LCA)

What is LCA?

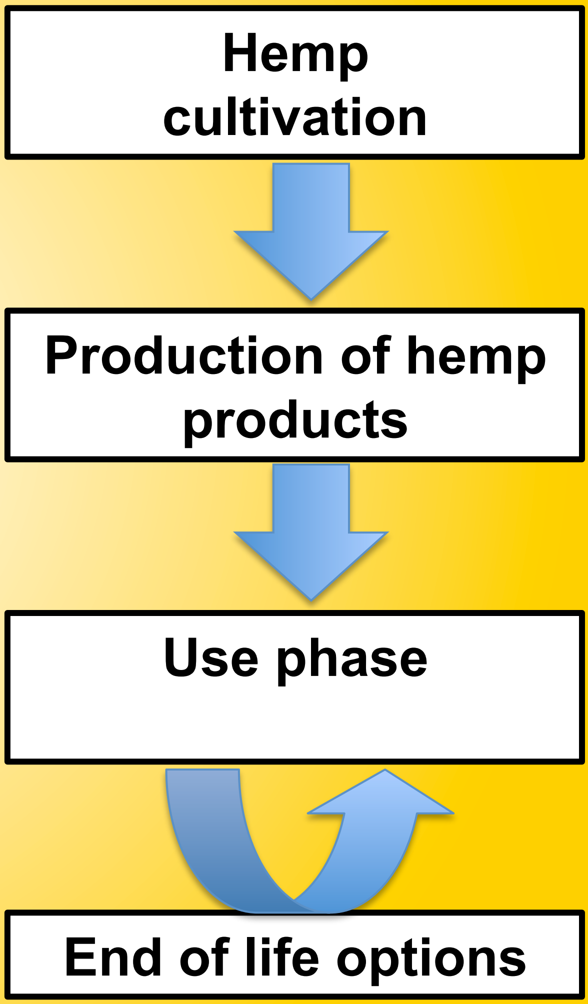
Life cycle assessment (LCA)

- is an internationally standardised method (DIN EN ISO 14040)
- is used to evaluate the environmental impacts associated with product systems along their life cycle from “cradle to grave”
- is based on scientific knowledge
- has been developed since more than 20 years
- is still improving (e.g. CEN TC 411)

What are the key characteristics of LCAs considering hemp products?

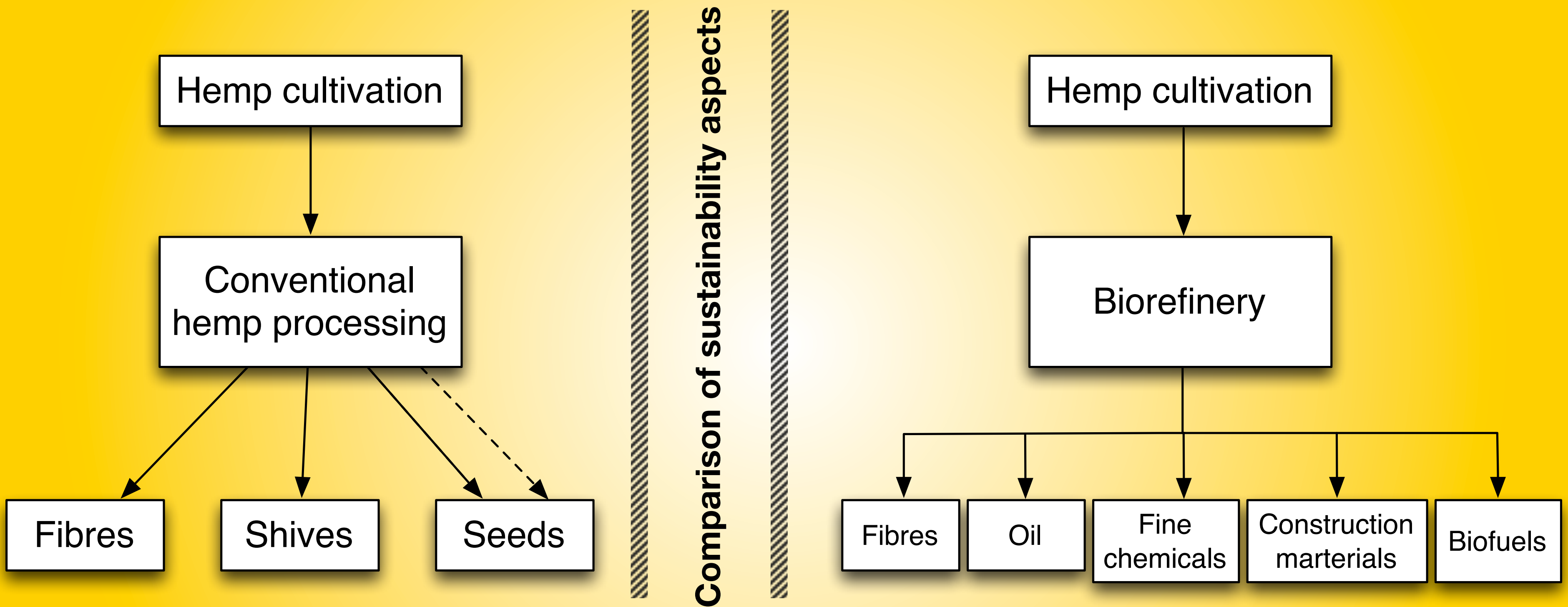
LCAs of hemp products can show

- complex multi-output production processes with valuable by-products (fibres, shives, dust, etc.)
- the ability to store atmospheric carbon within the product during the use phase
- different end-of-life options and the possibility for cascade utilisation (sequential material use before the product is finally used for energy purposes)



2) Preliminary LCA results for hemp fibre production

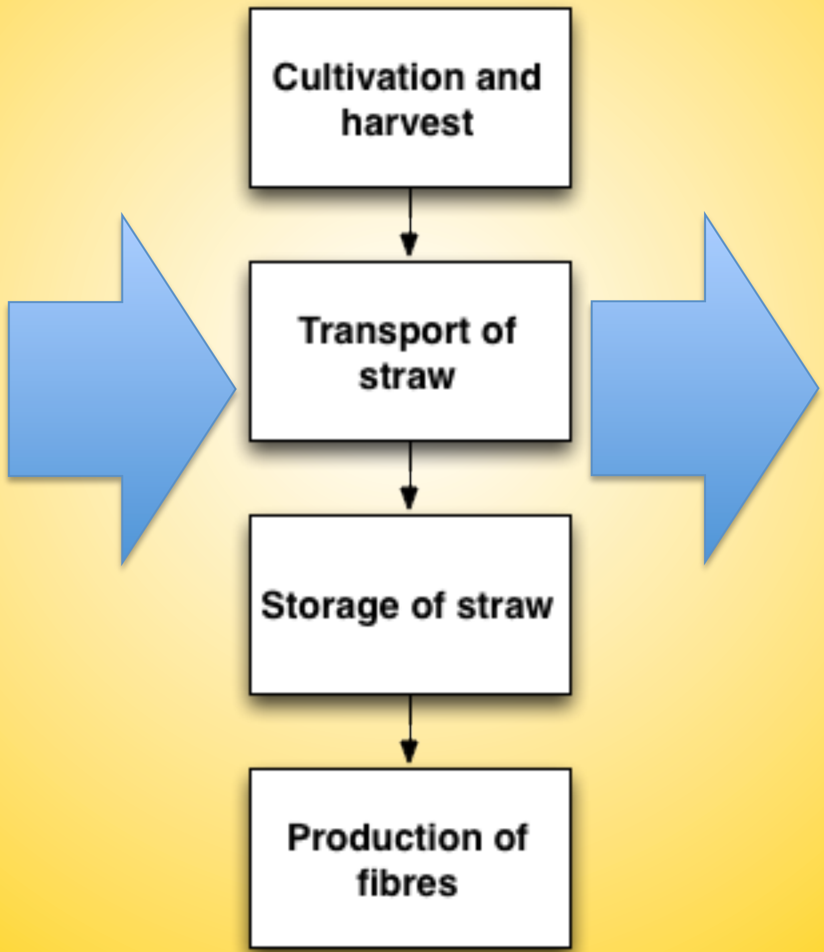
The MultiHemp approach



Life cycle of hemp fibre production ("cradle-to-gate")

<u>Inputs</u>

- Materials (fertilizer, pesticides, etc.)
- Energy flows (electricity, heat, etc.)



<u>Outputs</u>

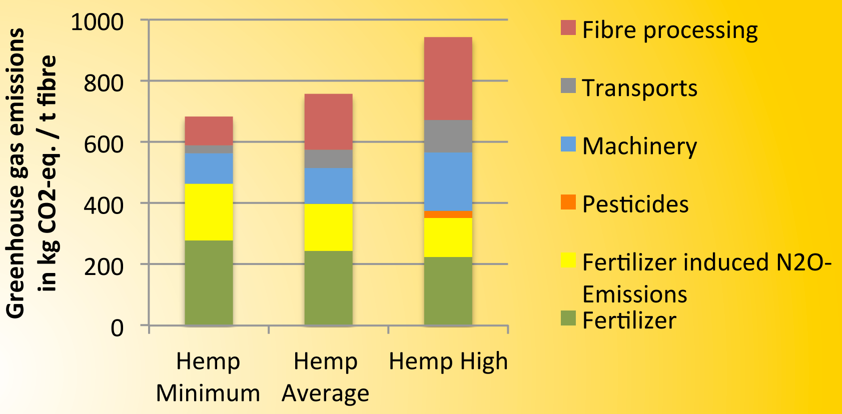
- Materials (products, by-products)
- Emissions (carbon dioxide, etc.)

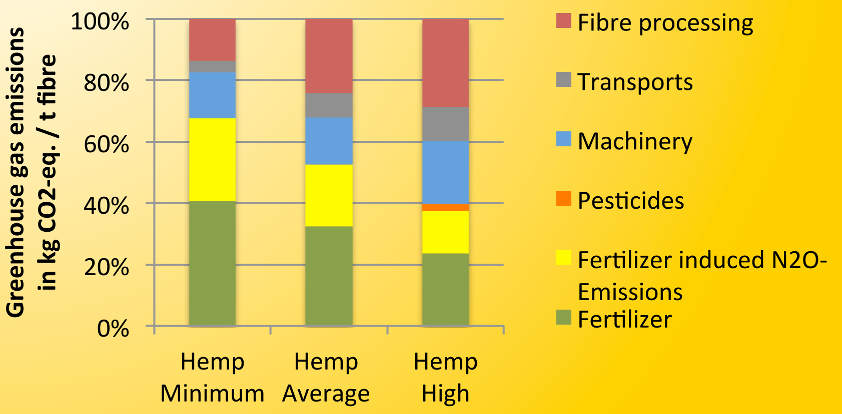
Description of 3 scenarios

Hemp Minimum	Hemp Average	Hemp High
– low intensity farming processes – short transport distance – low energy use for fibre processing – poor fibre content in straw – high production losses (filter dust, metals, stones)	– medium intensity farming processes – average transport distance – average energy use for fibre processing – average fibre content in straw – average production losses (filter dust, metals, stones)	– high intensity farming processes – maximum transport distance – high energy use for fibre processing – high fibre content in straw – low production losses (filter dust, metals, stones)

Greenhouse gas emissions of hemp fibre production

- **Agricultural production is very important**
  - **60% to 83% of the total GHG emissions**
- **Transports account for 4 – 14% of the total GHG emissions**
- **Impact shift from raw material production to fibre processing (in absolute and relative terms) considering scenarios from „Hemp Minimum“ to „Hemp High“**





3) Discussion of critical aspects: Allocation procedures

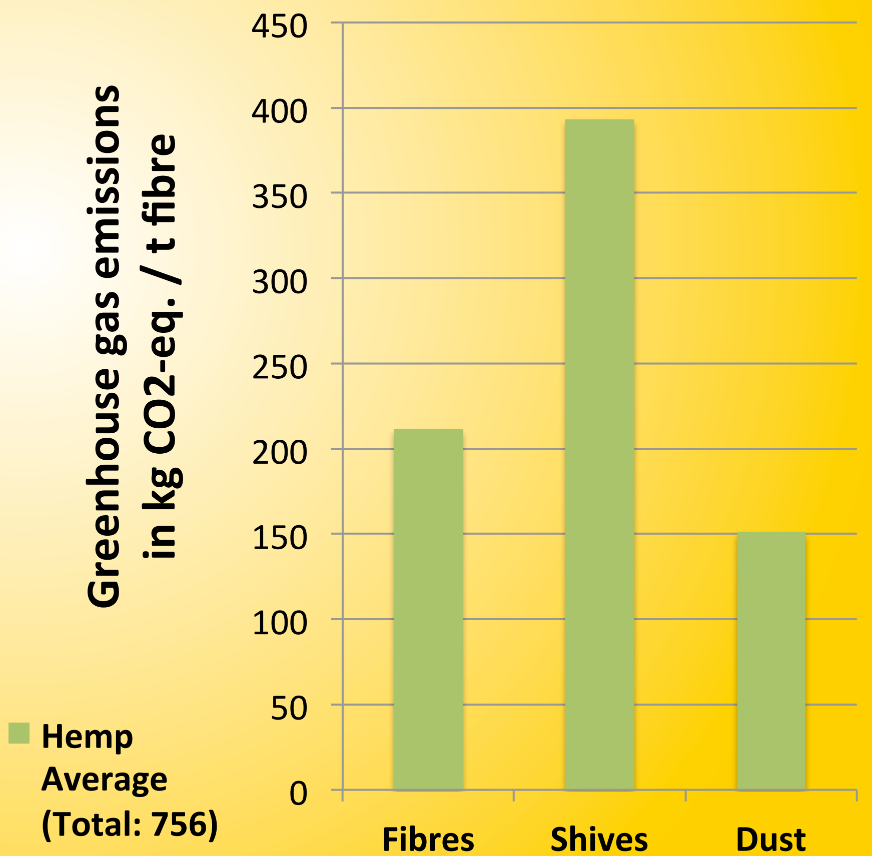
Allocation of environmental impacts

- Hemp fibre production is a multi-output process producing fibres, shives and dust (filter dust, metals stones, fibre wastes etc.) and/or seeds
- Allocation procedures are necessary to allocate the environmental impacts to the products and by-products by
  - mass
  - economic value
  - energy content (not useful for fibres)
- System expansion is also possible (credits for by-products which substitute conventional counterparts)

Allocation by mass

Mass distribution and greenhouse gas emissions of products and by-products according to sensitivity analysis: Average values

Product / by-product	Mass distribution (%) for hemp total fibre line
Fibres	28
Shives	52
Dust	20
TOTAL	100

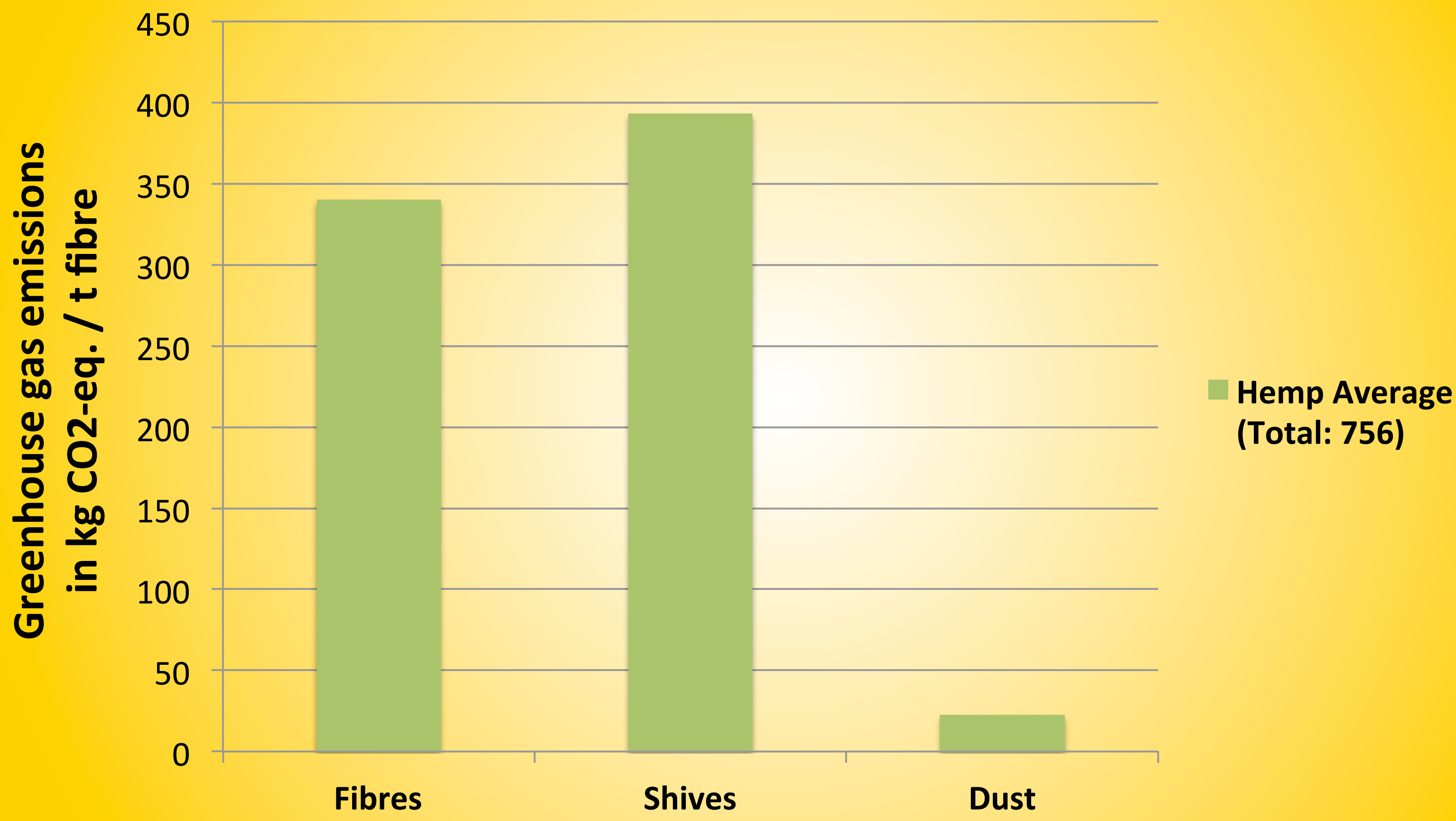


Allocation by price for hemp total fibre line

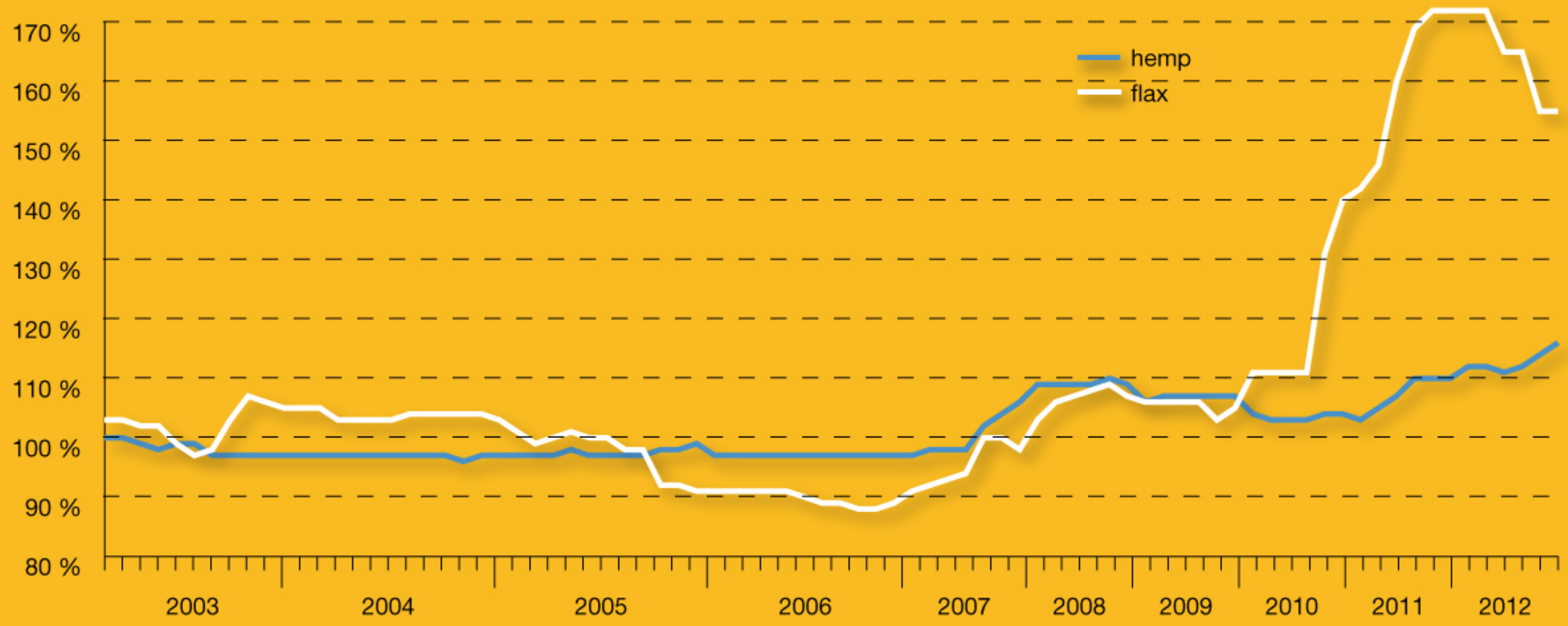
Production, prices and revenue of products and by-products according to sensitivity analysis: Average values

Product / by-product	Production in t	Prices in €/t	Revenue in €	Revenue in %
Fibres	1	650	650	45
Shives	1,86	400	744	52
Dust	0,71	50	36	3
Total	3,57	-	1430	100

Allocation by price for hemp



Price index:
Hemp and flax technical short fibres



100 % equal the price of technical hemp short fibres in March 2003. Basis: Supply of 100 t per year.

Sources: nova-Institute GmbH on the basis of bi-monthly price reports from: Agrofibre SAS (F, since 2009), Badische Naturfaseraufbereitung BaFa GmbH (D), Hemp Technology Ltd. (UK), HempFlax B.V. (NL), Holstein Flachs GmbH (D), Linolitas (LT, until 2007-12), NAFGO GmbH (D, until 2008), Procotex SA Corporation (B, until 2005-10), Sachsen-Leinen GmbH (D, since 2003-10), SANECO (F, since 2008).

Resume

- **Allocation procedures have a strong influence on the LCA results for fibre production:**
  - **Mass allocation shows consistent LCA results according to the material flows of conversion technologies**
  - **Price development of fibres is a key driver for LCA results calculated with economic allocation**

3) Discussion of critical aspects: Carbon storage

How much biogenic carbon is stored in hemp fibre?

- **1 kg hemp fibre contains:**

Component	Mass distribution (kg)	Carbon content (%)	Embedded carbon (kg)
Cellulose	0.650	40	0.260
Hemicellulose	0.150	40	0.060
Lignin	0.100	60	0.060
Water	0.100	0	0
TOTAL	**1.000**	**100**	**0.380**

→ **38 % of the fibre mass is "embedded carbon"**

→ **380 g biogenic carbon is stored in each kilogram of hemp fibre**

How much CO_2 is stored in 1 kg hemp fibre?

Oxidation of carbon

1 mole carbon + O_2 = 1 mole CO_2

Conversion factor: $\frac{44 \text{ g/mole}}{12 \text{ g/mole}} = 3.666$

with

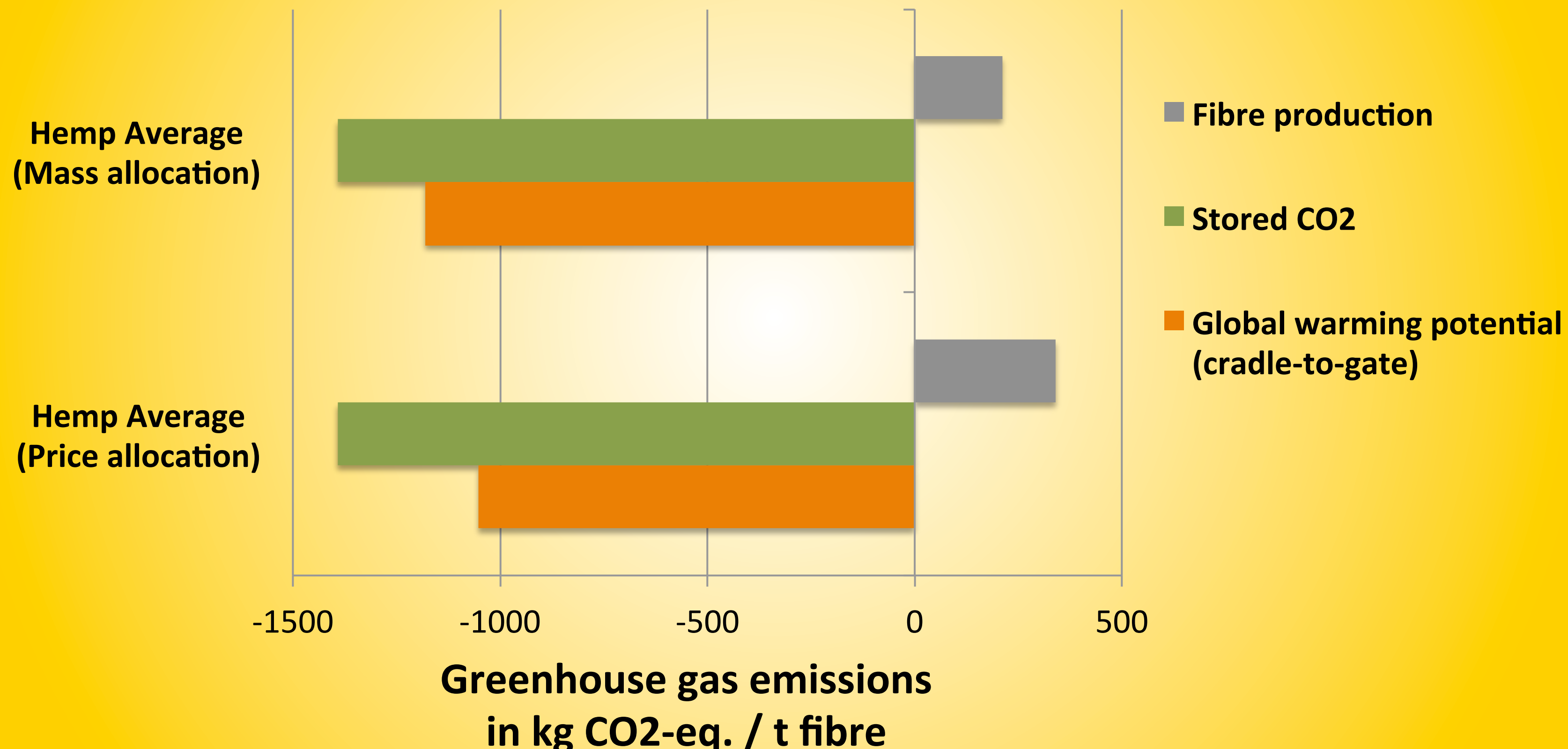
- 1 mole carbon dioxide (CO_2) = 44 g/mole
- 1 mole carbon = 12 g/mole
- 1 mole oxygen = 16 g/mole

Therefore, we calculate

0.380 kg C * 3.666 = 1.393 kg CO_2

→ 1.393 kg carbon dioxide is stored per kg hemp fibre

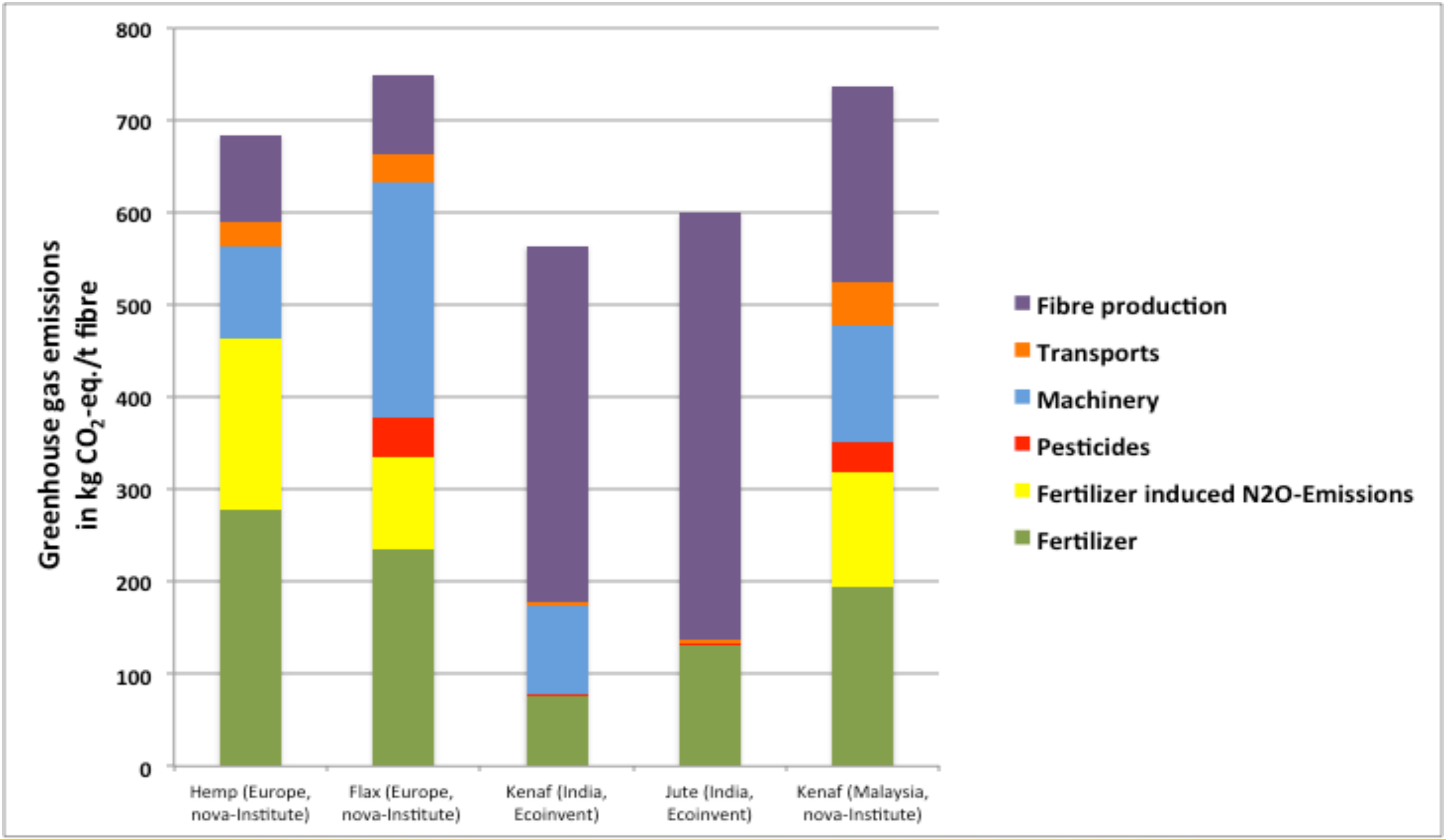
Influence of carbon storage on greenhouse gas emissions of hemp fibre production



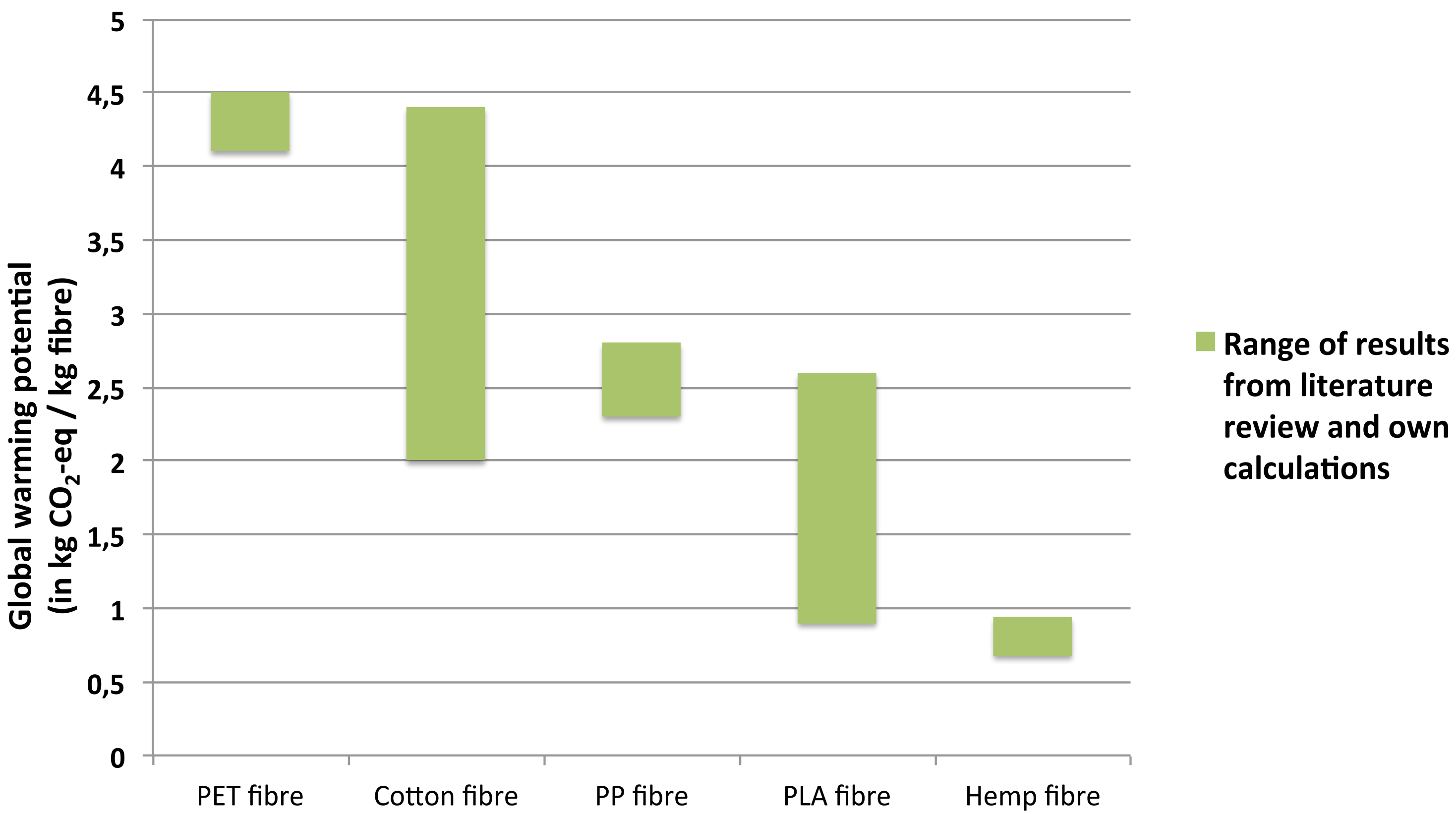
According to sensitivity analysis: Scenario average

4) Literature review – Hemp vs. natural and synthetic fibres and insulation materials

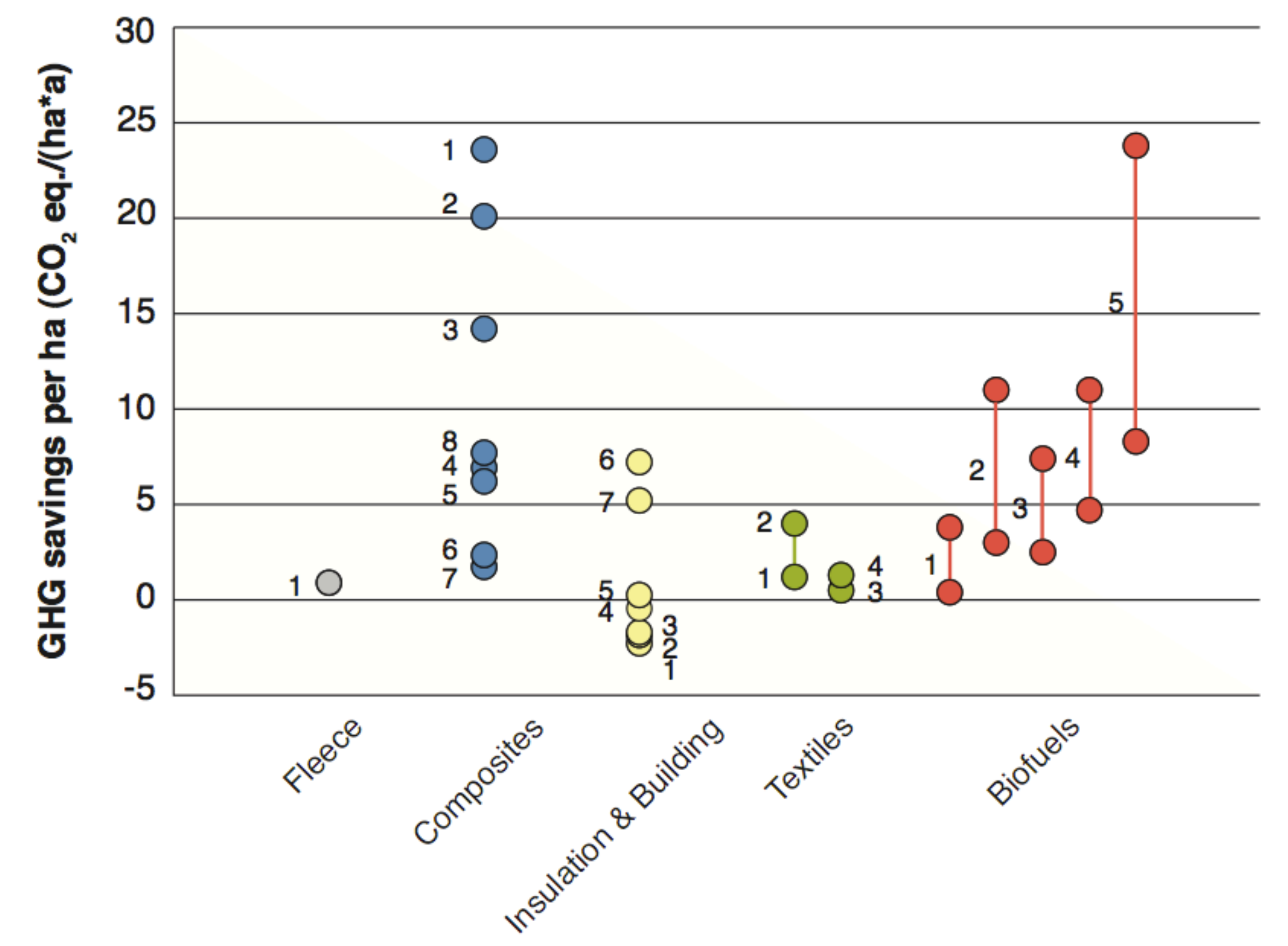
Greenhouse Gas emissions of different natural fibres



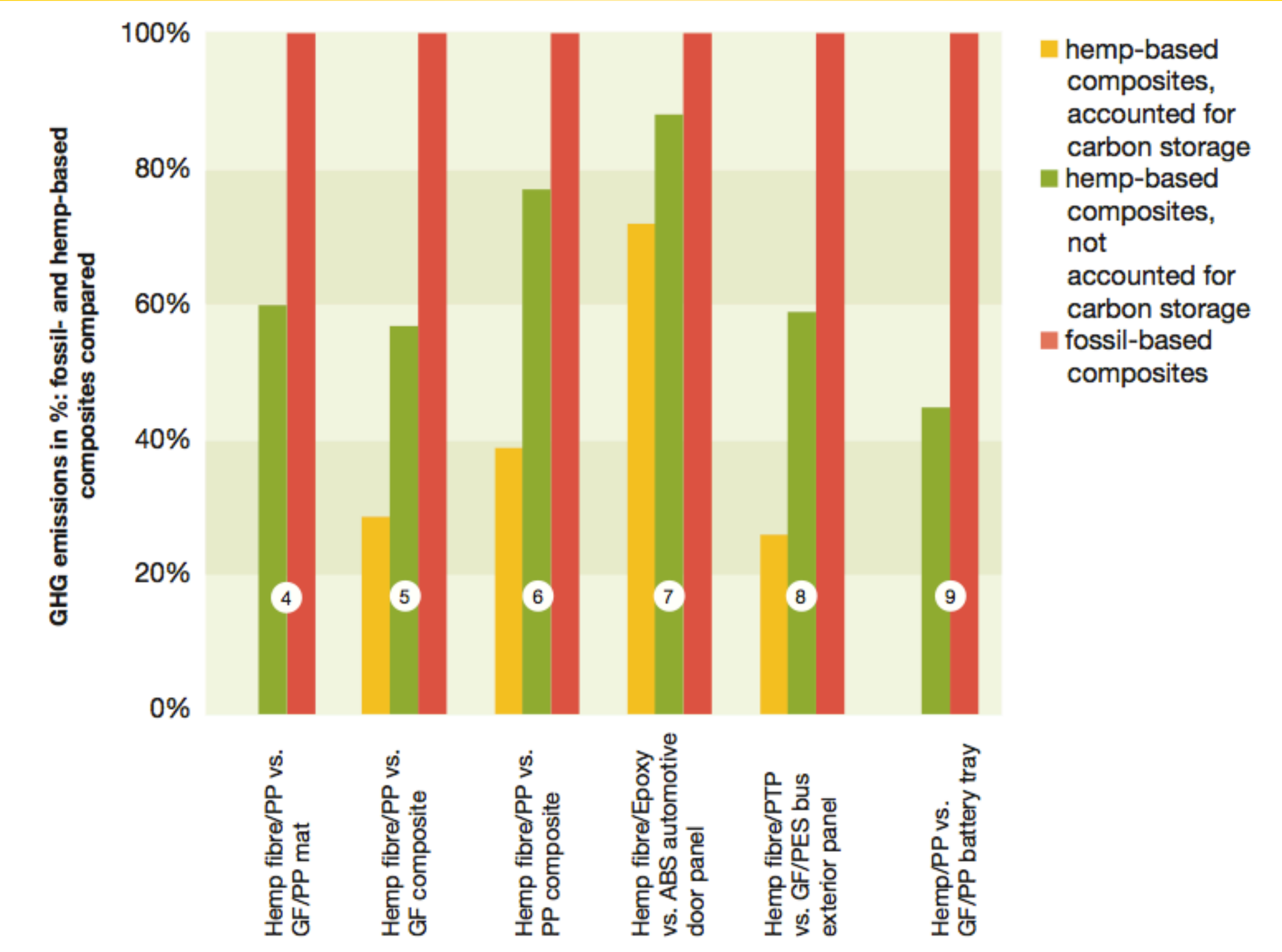
Greenhouse Gas emissions of different synthetic and natural fibres



Greenhouse gas emission (GHG) savings per hectare and year for different hemp fibre applications



Greenhouse gas emissions (GHG) of hemp-based composites in comparison with their fossil counterparts



State of the Art: Insulation material – less solid data compared to biocomposites

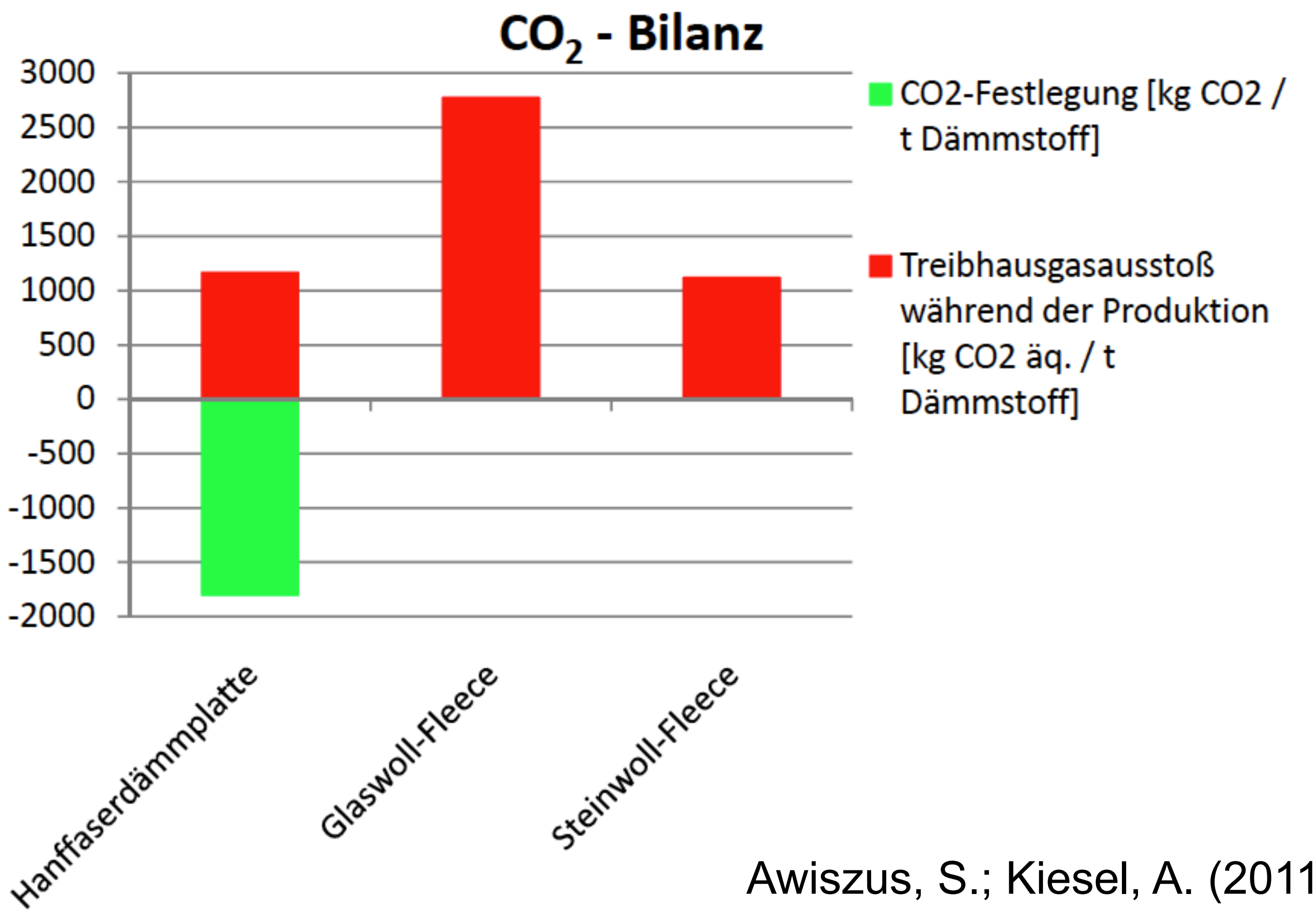
„The quality of the individual studies on hemp insulation and subsequent mineral counterparts do not allow clear recommendations on the preferability of one or the other material.

Haufe et al, 2011

Recent literature

IP et al (2012) I Awiszus, S. (2011) I La Rosa et al (2013) I Zampori et al (2013)

Example



Awiszus, S.; Kiesel, A. (2011)

Thank you for your attention!

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