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World Ethanol 2005

Energy and Greenhouse Gas Balances for State-of-the-Art and Innovative Ethanol Production Processes

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meó CONSULTING TEAM

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1 Rationale for new energy and GHG balances

The use of bioethanol as a renewable fuel has been considered controversial. Critics argued, that GHG balances were not very favourable

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- There is a large number of studies on energy and GHG balances showing a wide range of results
- Many studies have not made allowances for improvements in efficiency of agricultural feedstock production, optimisations and innovations in the conversion process
- Several studies do not provide transparency regarding underlying assumptions, system boundaries and key energy figures used for the calculations
- Many studies are difficult to under-stand for readers outside the scientific world. The usability for decisionmakers is limited

Against this background, the German Federal Ministry of Consumer Protection, Food and Agriculture / Agency of Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V.) commissioned meó to carry out a energy and GHG balance study, taking into account state-of-the-art as well as innovative production processes and technologies

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In close cooperation with research institutes and industry, new energy and GHG balances have been developed for nine different production processes

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Company	Capacity	Feedstock	Pertinence for study
ABENGOA	176.000 m³ (Bioetanol Galicia)	– Cereals – Wine alcohol	European bioethanol market leader, large scale production
Royal Nedalco	90.000 m³	– Molasses – C-starch	Leading position in the European traditional market. Use of side stream
AGROETANOL	50.000 m³	– Cereals (in particular wheat)	Leading bioethanol producer in Scandinavia. Medium-sized plant, energy supply
KWST	30.000 m³ 60.000 m³	– Molasses – Cereals (all kinds)	Current status quo of ethanol production in Germany; innovative, energy saving process for grain
SÜDZUCKER	90.000 m³	– Sugar beet	Sugar beet as feedstock
IOGEN CORPORATION	220.000 m³	– Wheat straw	Lignocelluloses as feedstock
Universität Hohenheim 1818 – Agricultural Distillers	9.000 m³	– Cereals (rape seed)	Agricultural small scale plant vs. industrial large scale plants

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2 Analysis of existing studies

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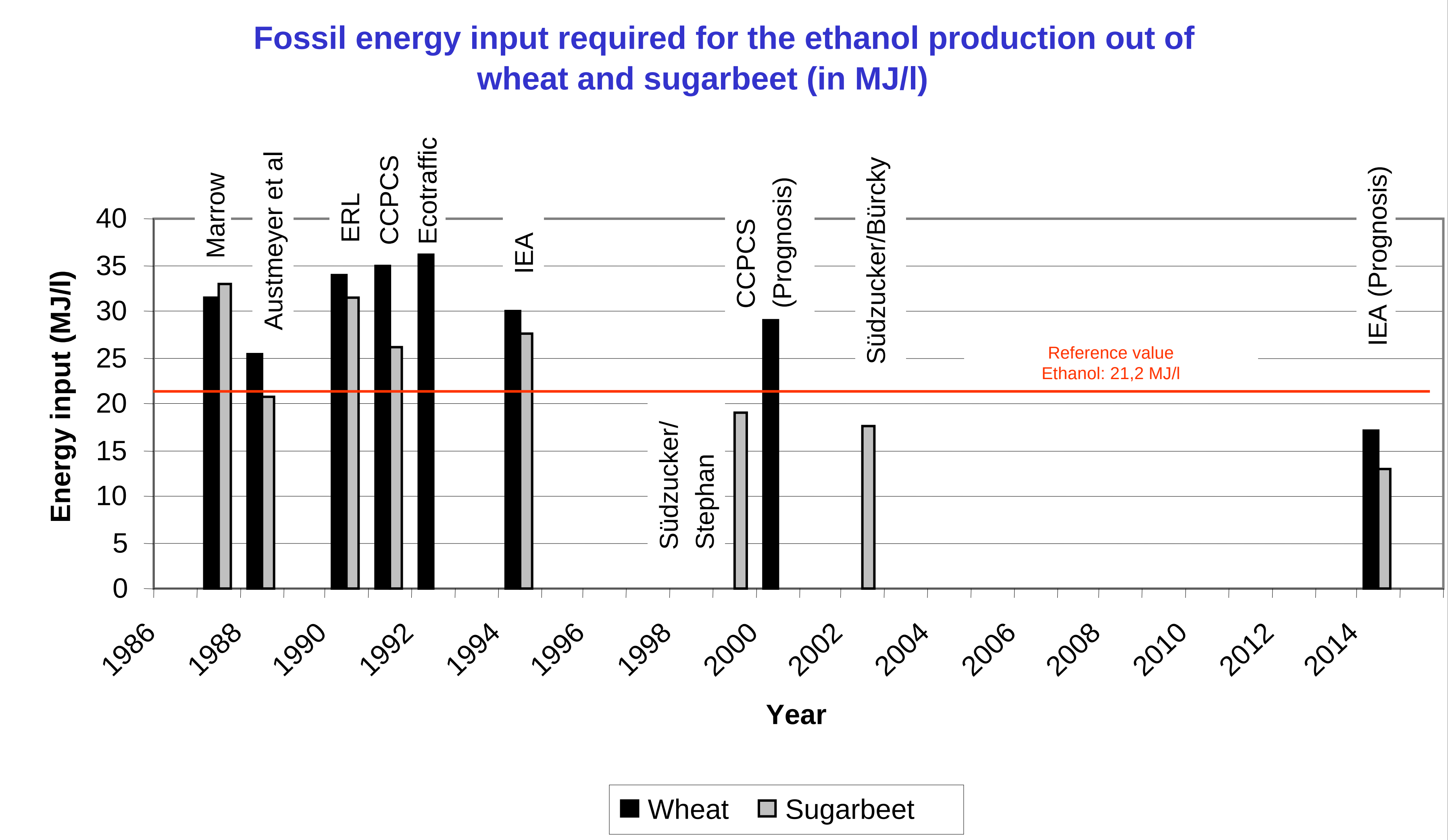
Older studies concluded that the energy balance of the production of ethanol is negative, resulting in a negative perception of ethanol as a fuel



Source: FNR: Bioethanol in Deutschland

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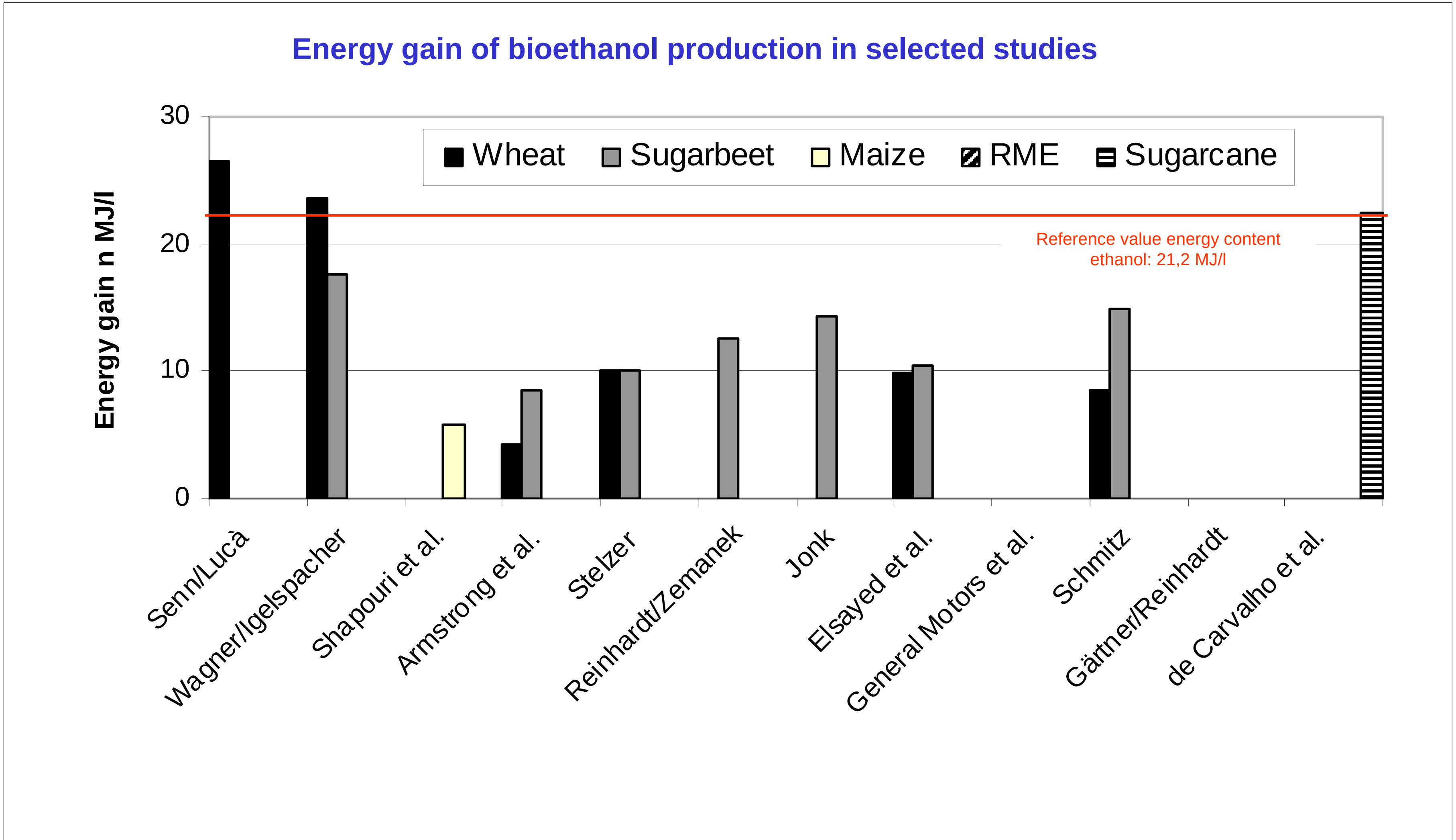
All of the analysed, more recent studies show energy gains



Variations in the results of available studies are significant

Main factors influencing the energy and GHG balances

Agricultural production	Conversion	Use as a fuel
– Assumptions regarding the energy input required for fertilizer – Fertilizer input – Yields – Reference system – Valuation of by-products	– Size of processing plant – Process, Technology used – Process energy used – Valuation of by-products	– Energy substitution relationship between bioethanol and gasoline

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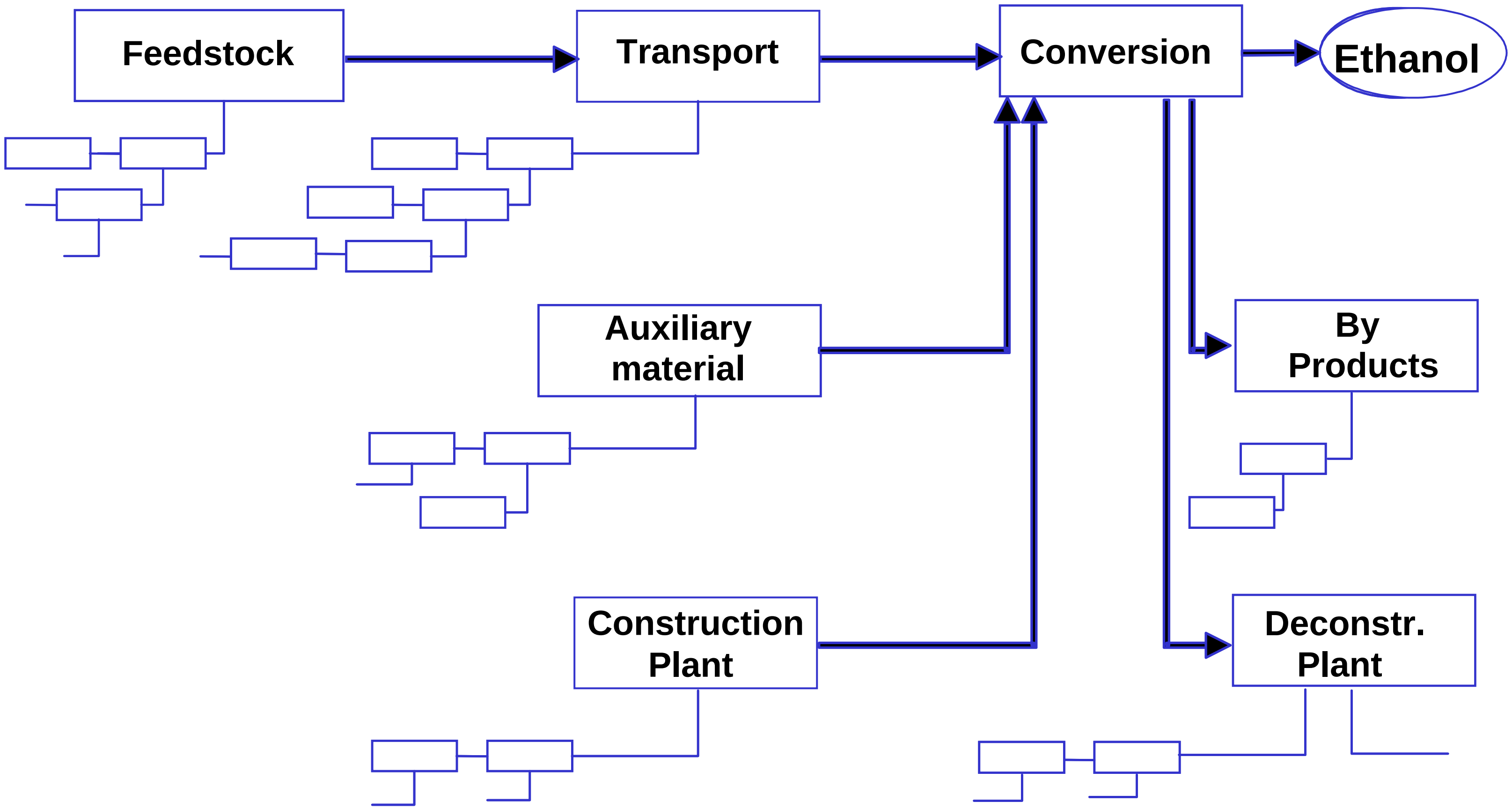
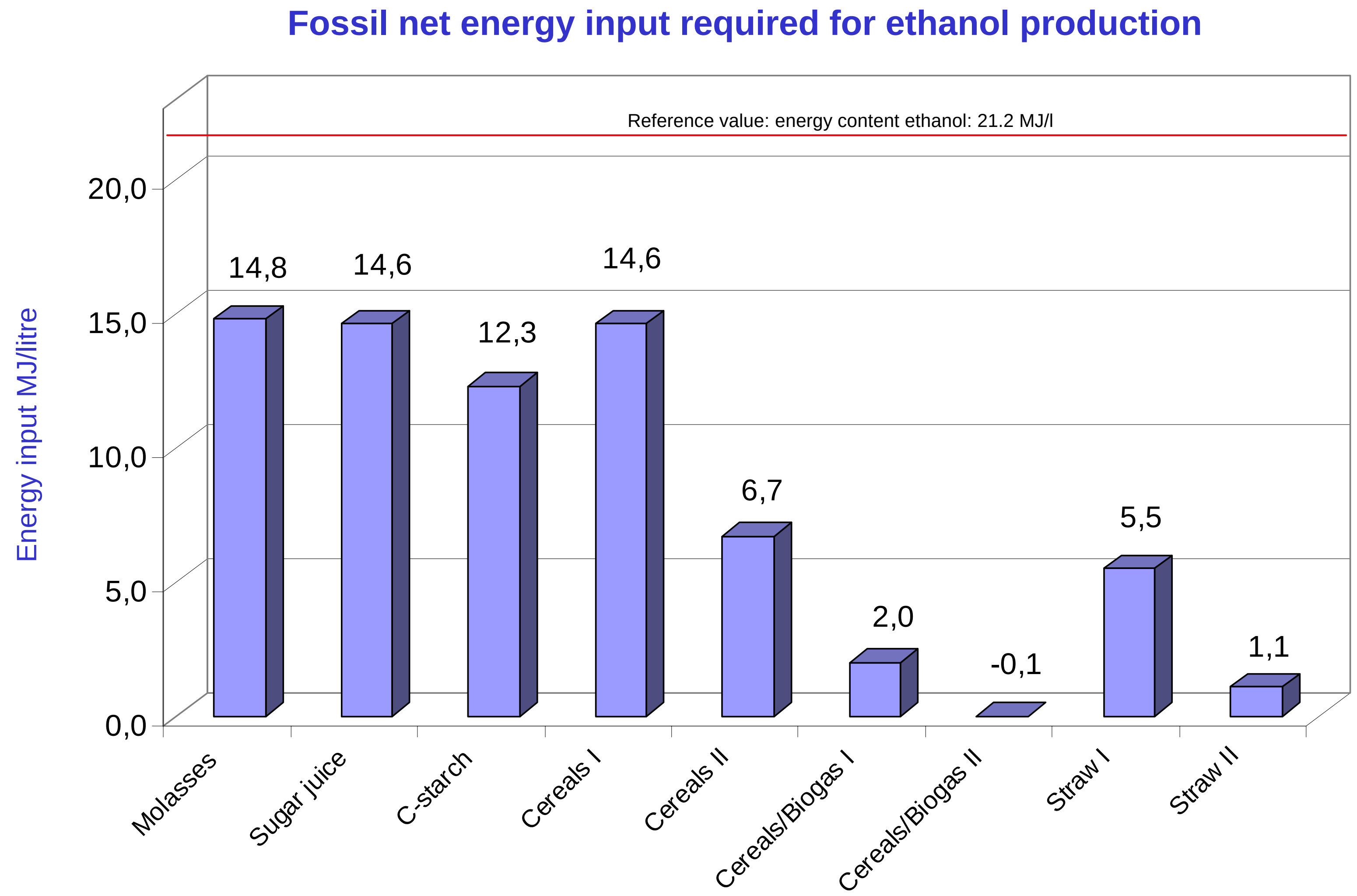
3 Energy & GHG balances for current & future production processes

Energy and GHG balances have been prepared based on an analysis of all inputs along the value adding chain



Accumulated fossil primary energy input in MJ per litre of bioethanol



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Current productions show similar energy consumption. Improvements are expected once the concepts are in place

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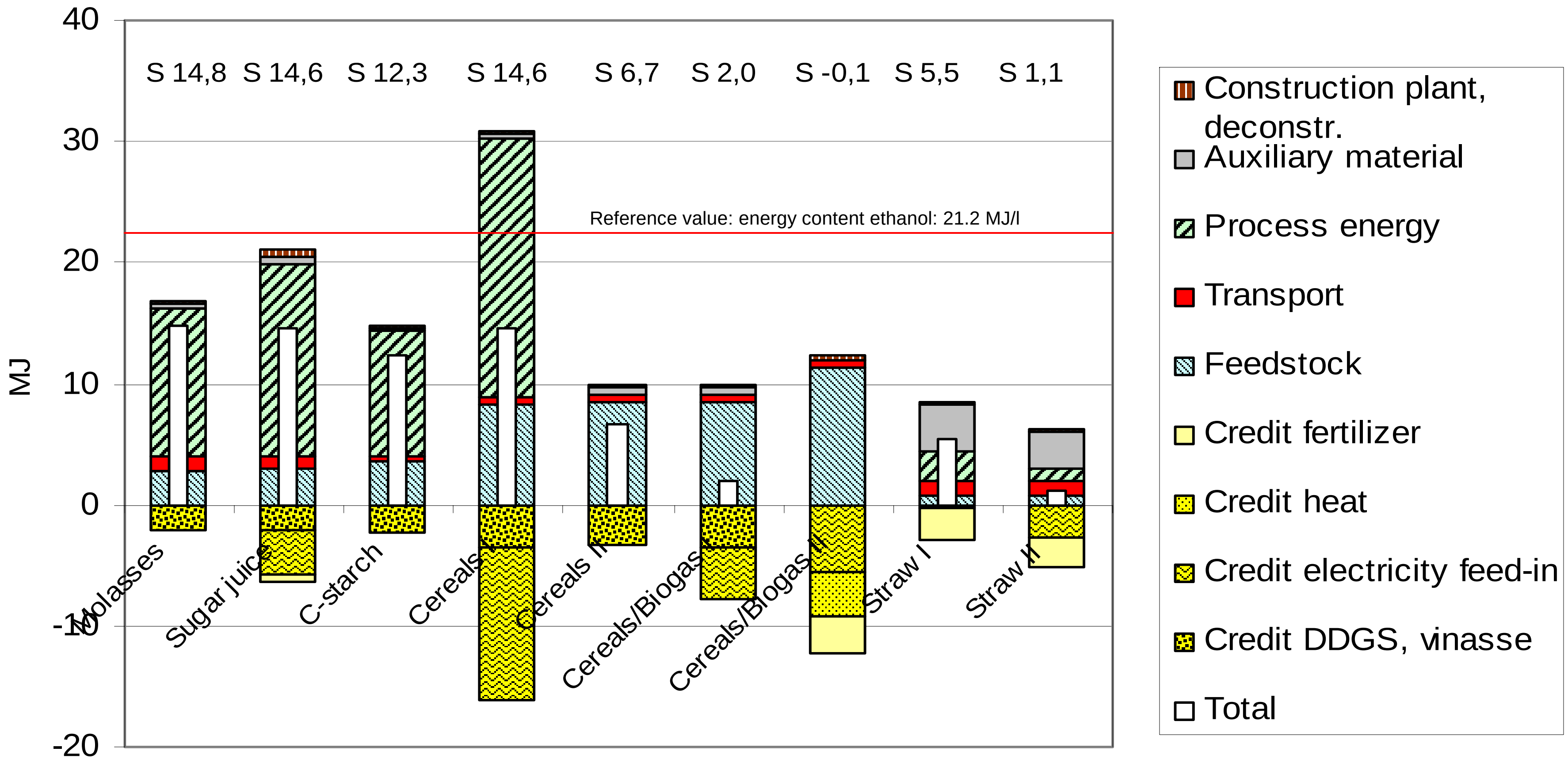
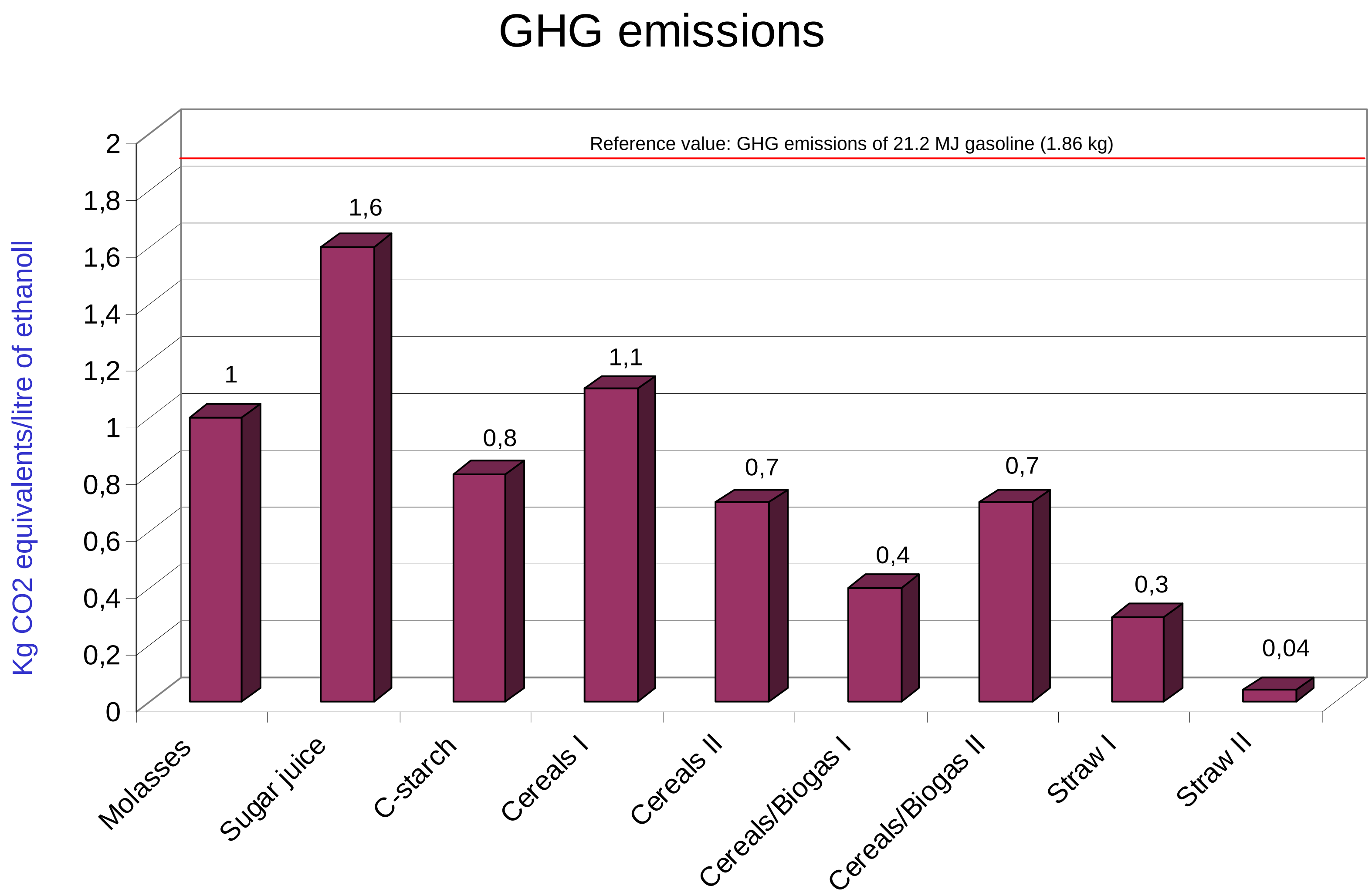
Energy balance



GHG emissions per litre of bioethanol



The highest GHG emissions occur with sugar juice /lignite plants, the lowest are expected with grain / biogas-concepts and the use of straw

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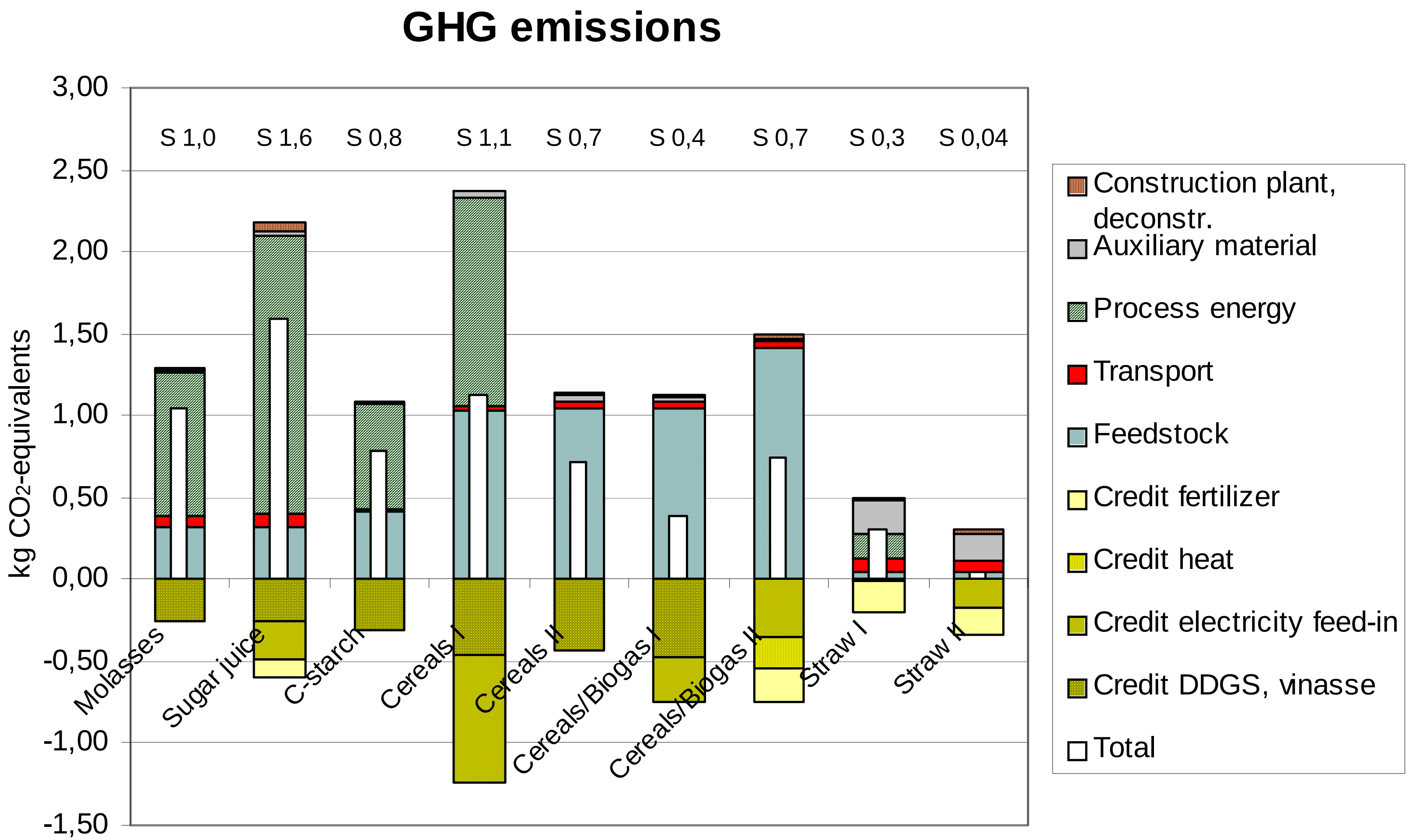

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Different approaches are applied in the concepts

Company	Approach
IOGEN CORPORATION	– Large scale production of „EcoEthanol“ out of wheat straw (patented process) – Chemically pretreating the lignocellulosic feedstock – Producing proprietary cellulase enzymes – Enzymatically hydrolyzing the cellulose to glucose – Fermenting the five-carbon and six-carbon sugars to ethanol and purifying the ethanol by distillation – Burning of the lignin to generate steam and power for the process
KWST	– Grain as feedstock – Reduction of investment and energy requirements for the treatment of the by-product DDGS. Energy consumption reduced due to changed and released process steps – Biogas use to generate energy (combined electricity and heat) and/or production of DDGS. Energy produced out of biogas is sufficient to cover the energy demand of the conversion process
UNIVERSITÄT HOHENHEIM 1818	– Concept of the University Stuttgart Hohenheim in cooperation with agricultural distilleries – Objective: sustainable ethanol production in the agricultural sector. Small and medium-sized production capacities – Anaerobic grain stillage processing is a core element of the concept. Stillage is not dried but used as fertilizer. Biogas production out of stillage and rapeseed/corn silage

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4 Conclusions

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All conversion paths show energy gains, and high GHG emission reductions can be achieved with the new concepts

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Conversion path/ used process energy	Net energy gain / litre of ethanol (MJ output ./. MJ fossil input)	GHG reduction / litre ethanol (CO_2-equivalent/0,647 l gasoline ./. kg CO_2-equivalent/l ethanol)
Molasses / heavy fuel oil	6.4 MJ	0.8 kg
Beet juice / lignite	6.6 MJ	0.3 kg
C-starch+molasses / natural gas	8.9 MJ	1.1 kg
Grain / natural gas	6.6 MJ	0.7 kg
Grain / waste	14.5 MJ	1.1 kg
Grain / biogas	19.2 – 21.3 MJ	1.1 – 1.5 kg
Straw / biogas	15.7 – 20.1 MJ	1.6 – 1.8 kg

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Using grain and at the same time straw for ethanol and biogas production would result in a substantial increase of energy yields per hectare

1. The study shows, that from a climate policy standpoint, the use of bioethanol as a renewable fuel is a strategic option (other, more promising options for the fuels sector not ready yet)

2. State of the art-production processes show relatively similar energy consumption

3. Different process energy sources have significant impact on GHG balances. The use of natural gas, waste or biogas has a very positive impact on the reduction potential

4. New production processes are very promising, showing tremendous improvements in energy and GHG balances

The new technologies will contribute not only to an improvement of energy and GHG balances but also to an improvement of the competitive-ness of the European ethanol industry

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