

Biogas as a resource efficient vehicle fuel

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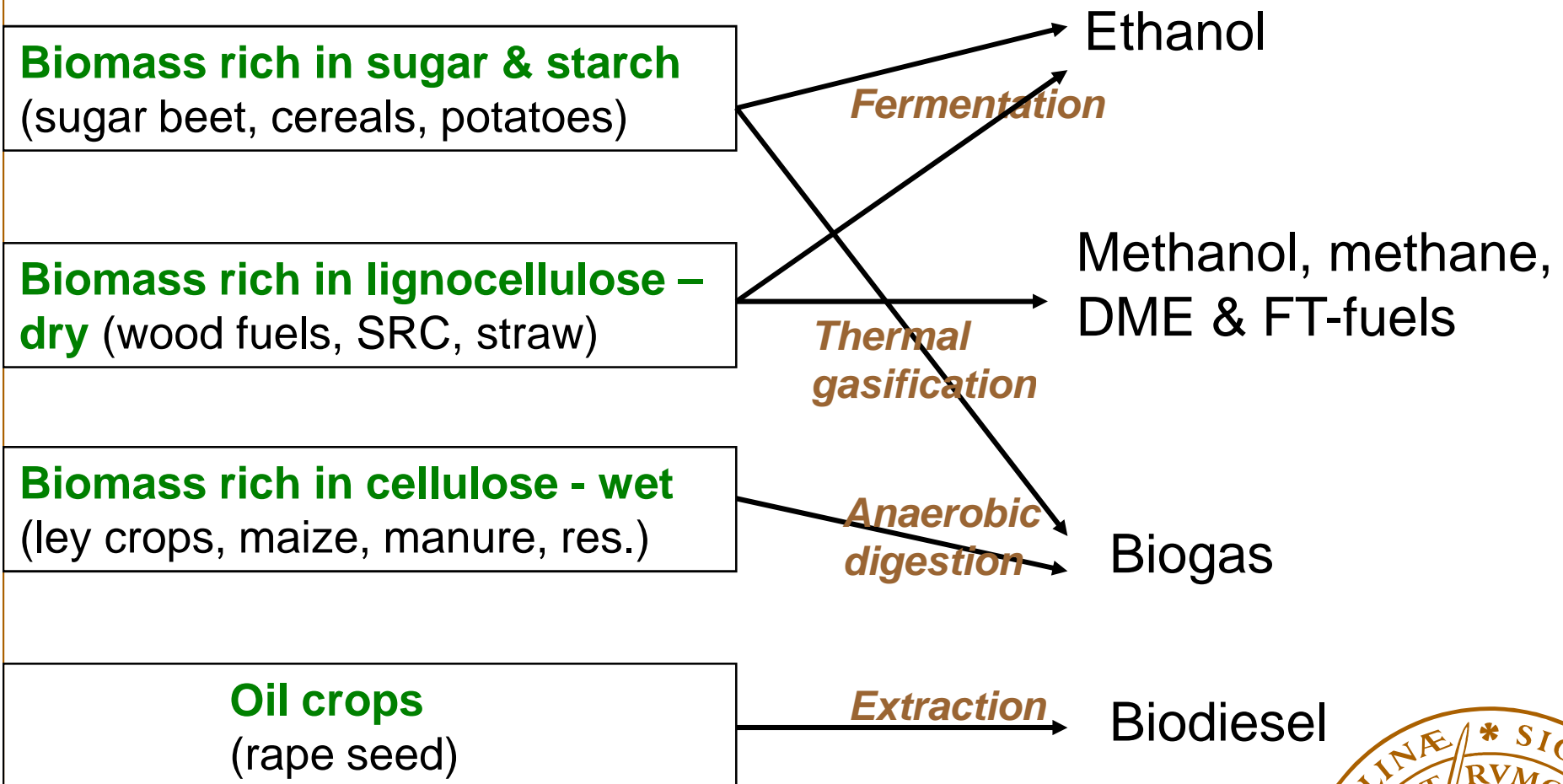


Efficient and sustainable biofuel systems

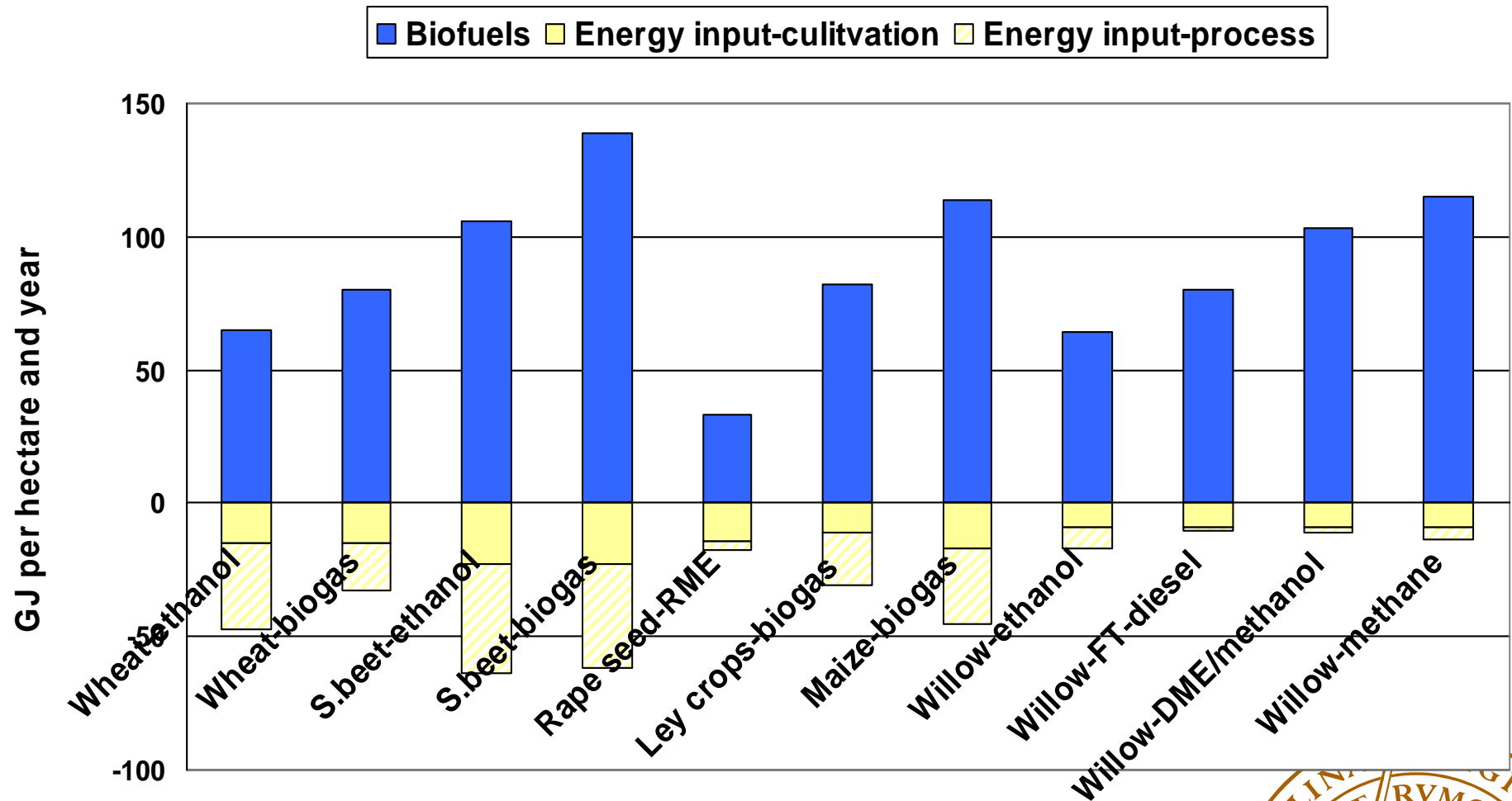
- **Resource efficient** (high biomass production per hectare, utilise existing residues and by-products)
- **Energy efficient** (minimise energy losses through the complete production chain)
- **Ecological sustainable** (maximise environmental benefits through the complete fuel cycle)
- **Cost efficient** (low production costs)



Potential production routes *(northern Europe)*



Output of biofuels, and input of energy, per hectare and year, for different biofuel systems

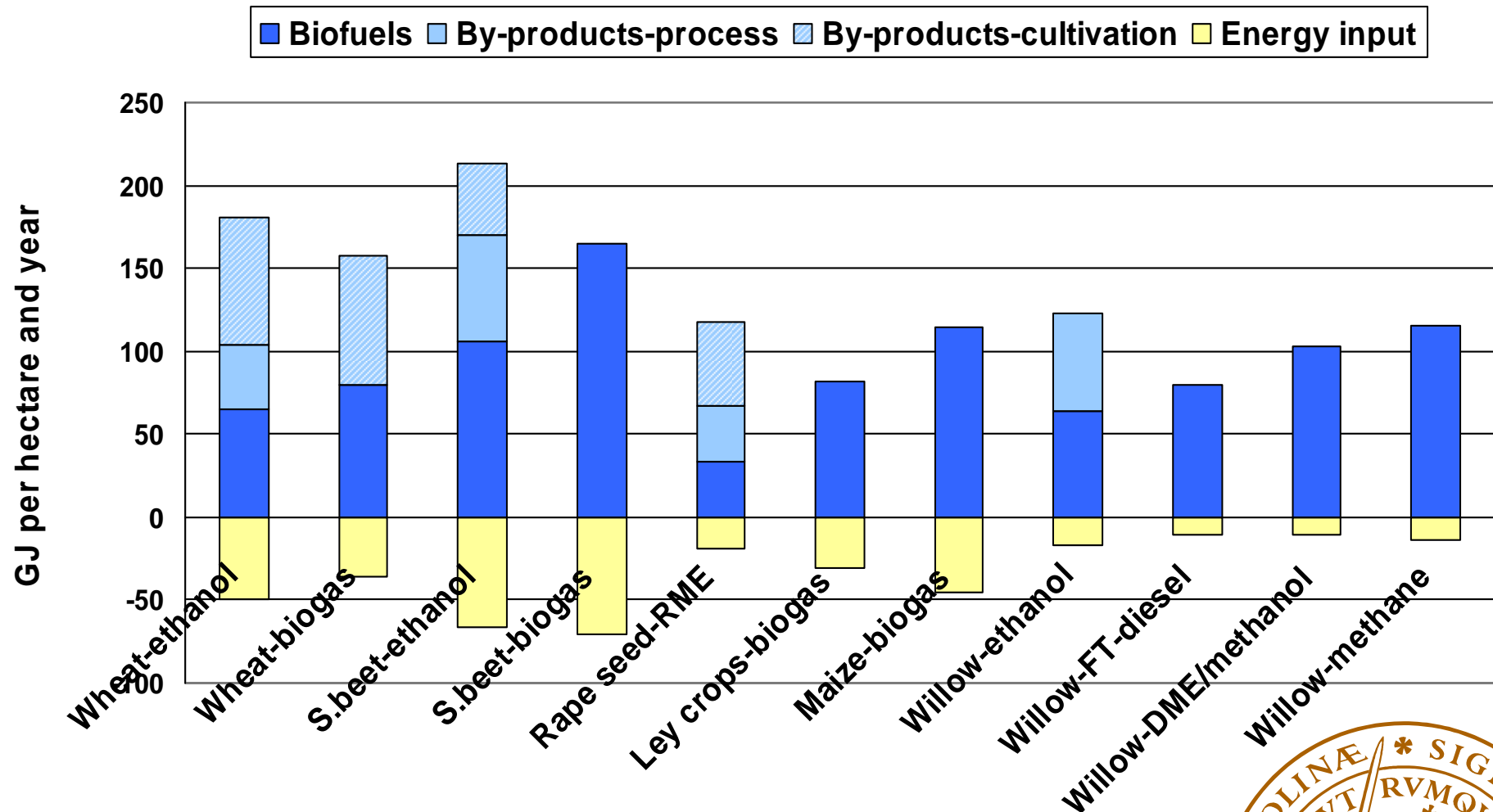


(Cultivation in northern Europe on average arable land)

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Output of biofuels and by-products, and input of energy, per hectare and year, for different biofuel systems

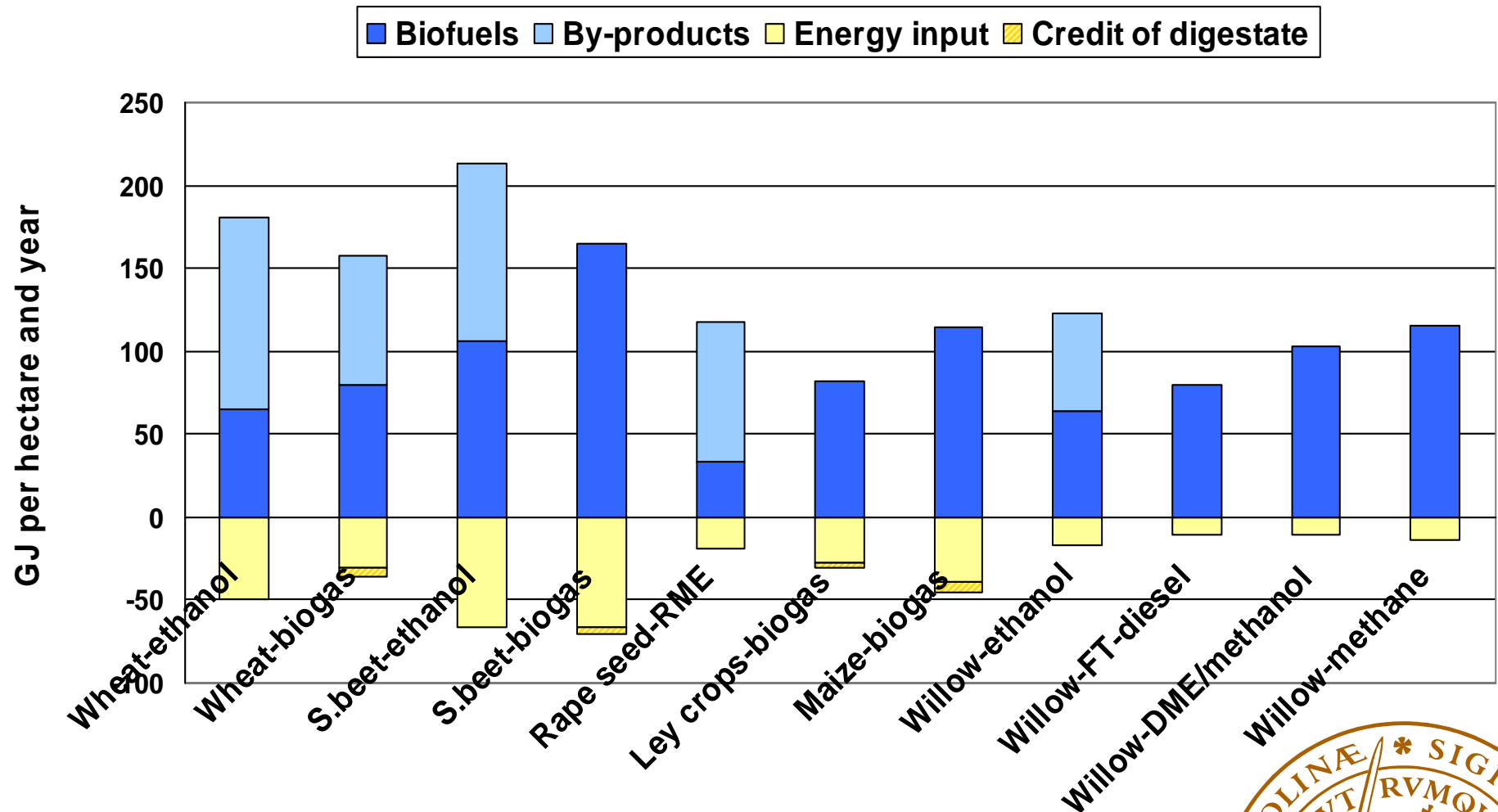


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Output of biofuels and by-products, and input of energy including credit of digestate, per hectare and year



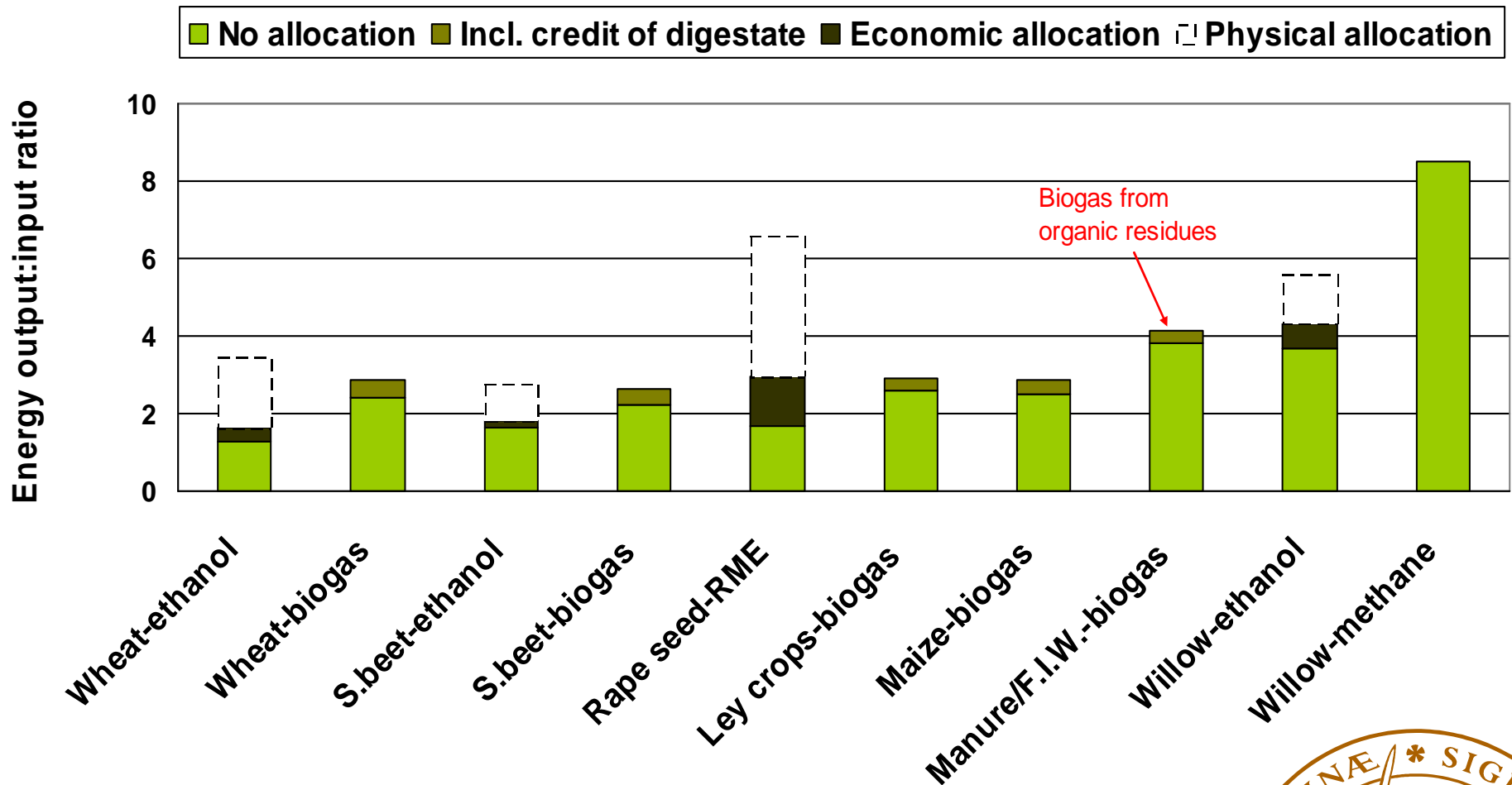
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Energy balance of different biofuels

(including by-products & credit of digestate)



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Energy balance – ethanol from wheat!

<i>Calculation method</i>	<i>Energy balance</i>
Current production system - all energy input allocated to ethanol	1,2
Current production system – energy input allocated (physical) to both ethanol and distiller's waste used for energy purposes (pellets)	1,9
Current production system - straw is harvested and utilised as fuel in the ethanol plant & energy input allocated to both ethanol and distiller's waste used as protein feed including indirect energy savings when replacing imported soy protein	5,2



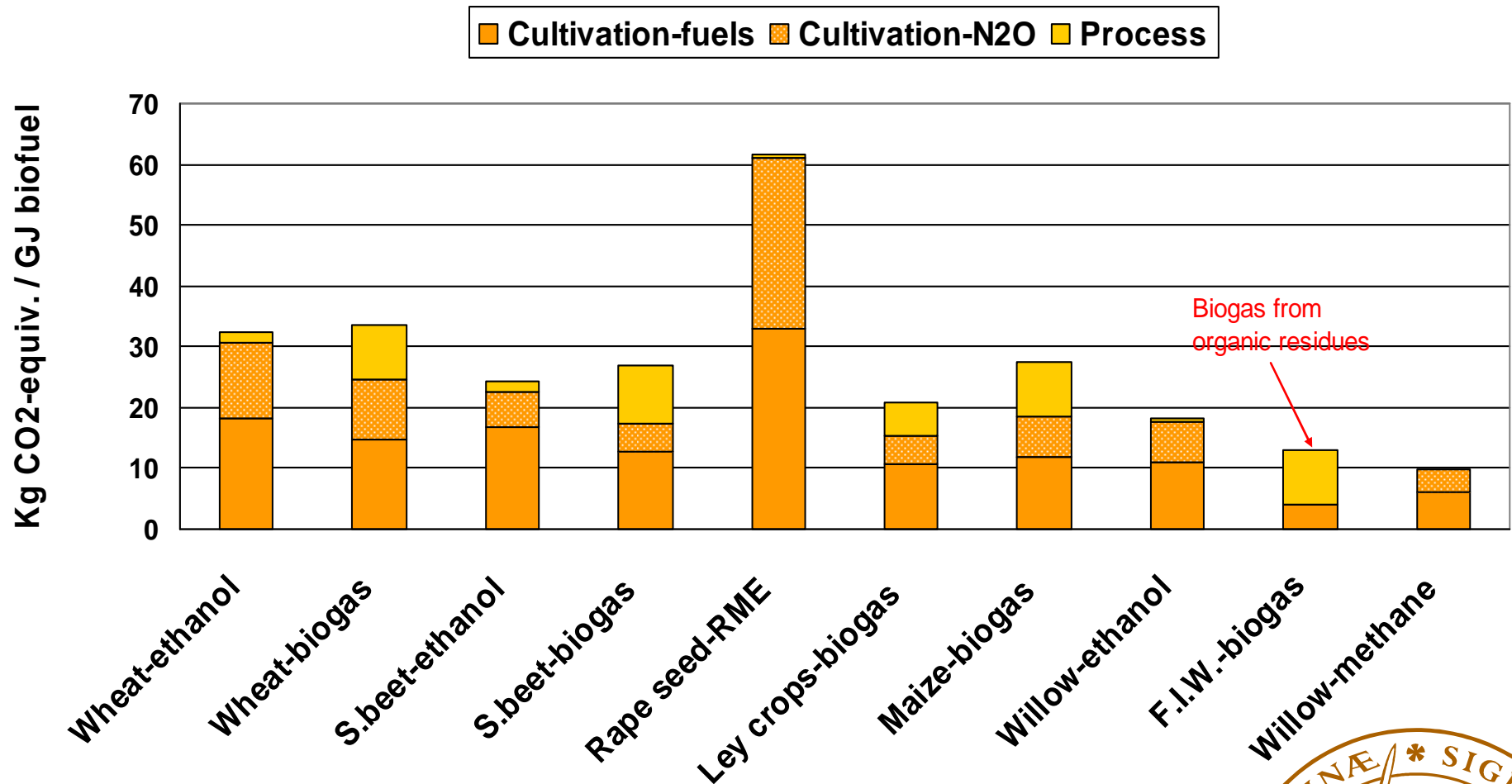
Why energy balances differ so much!

- Geographical localisation (climate, crops)
- Cultivation practices (fertilisation, harvesting practices)
- Yields (crops, conversion efficiency)
- Quality of the feedstock (content of sugar, starch, cellulose)
- Transportation systems (vehicles, distances)
- Conversion plant (technology, scale)
- Structure of the energy system (power production, fuels used)
- Quality of data (age, uncertainties)
- Systems boundaries (including by-products, etc)*
- Allocation methods (no, physical, economic, etc)*

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Contribution to the Global Warming Potential (GWP) regarding different biofuel systems (excl. by-products)

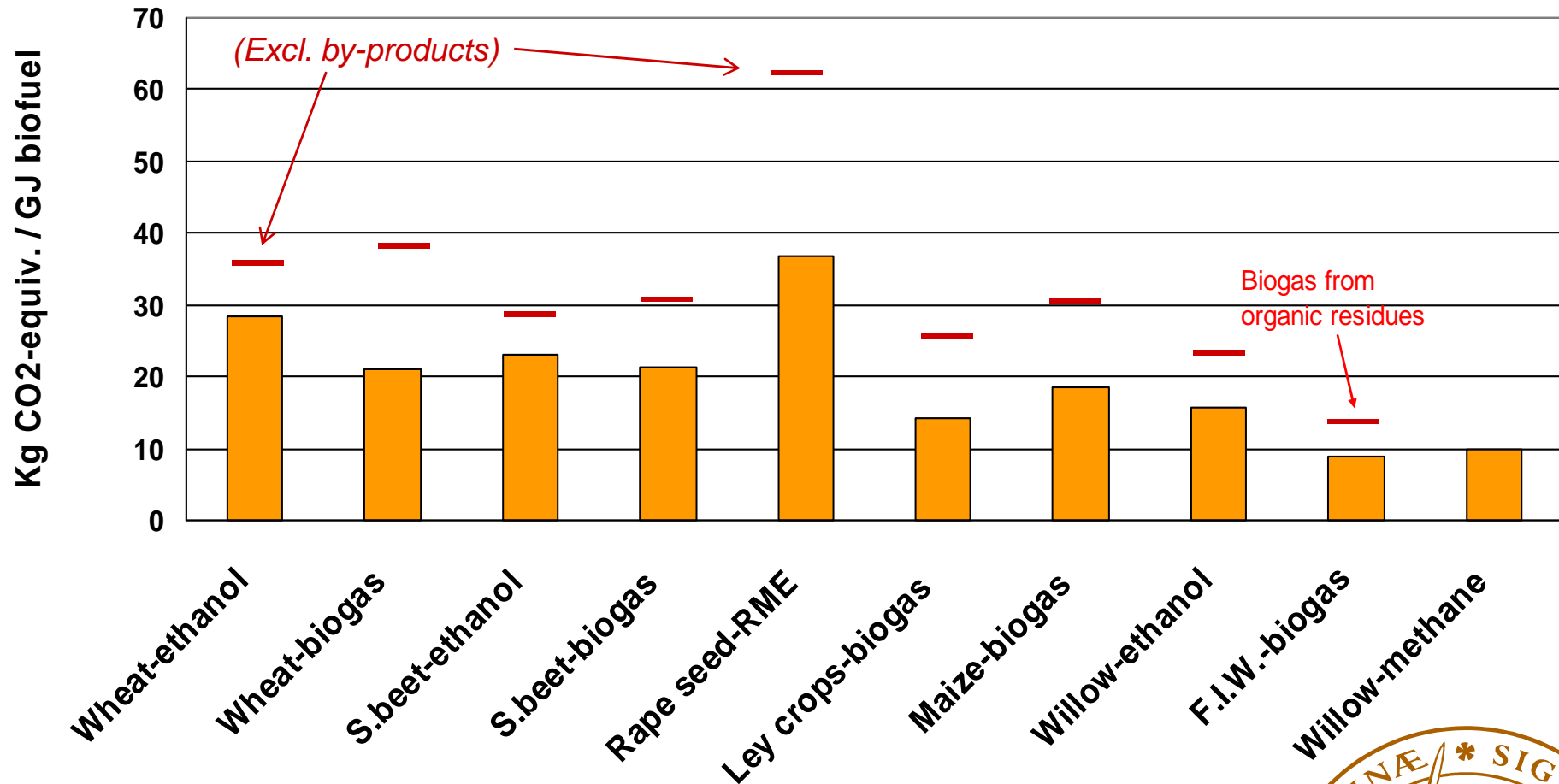


(Cultivation in northern Europe on average arable land, biofuel plant fuelled with CHP from wood chips)

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Contribution to the Global Warming Potential (GWP) (incl. economic allocation of by-products and credit of digestate)

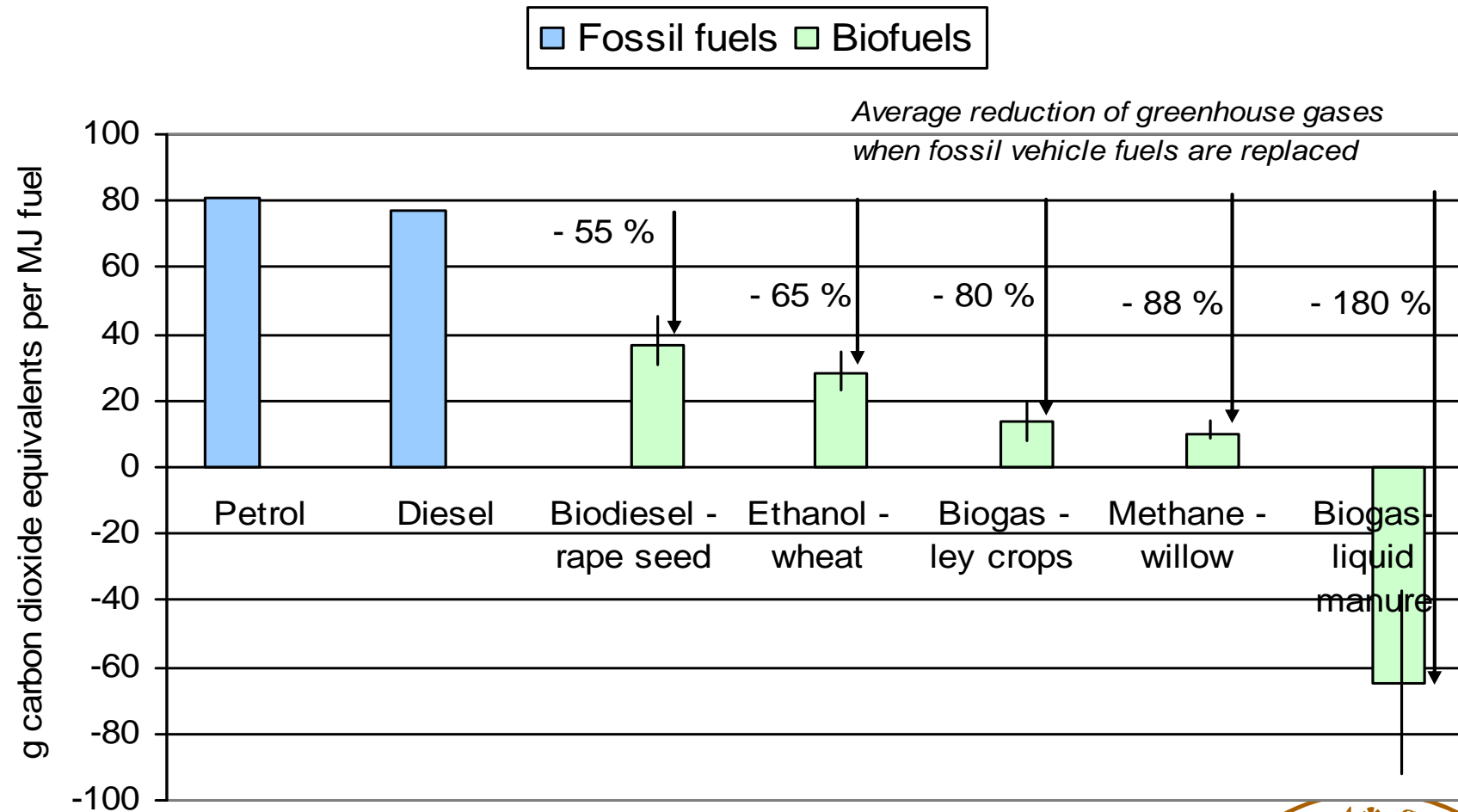


(Cultivation in northern Europe on average arable land, biofuel plant fuelled with CHP from wood chips)

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Emissions of greenhouse gases (*well-to-wheel*)

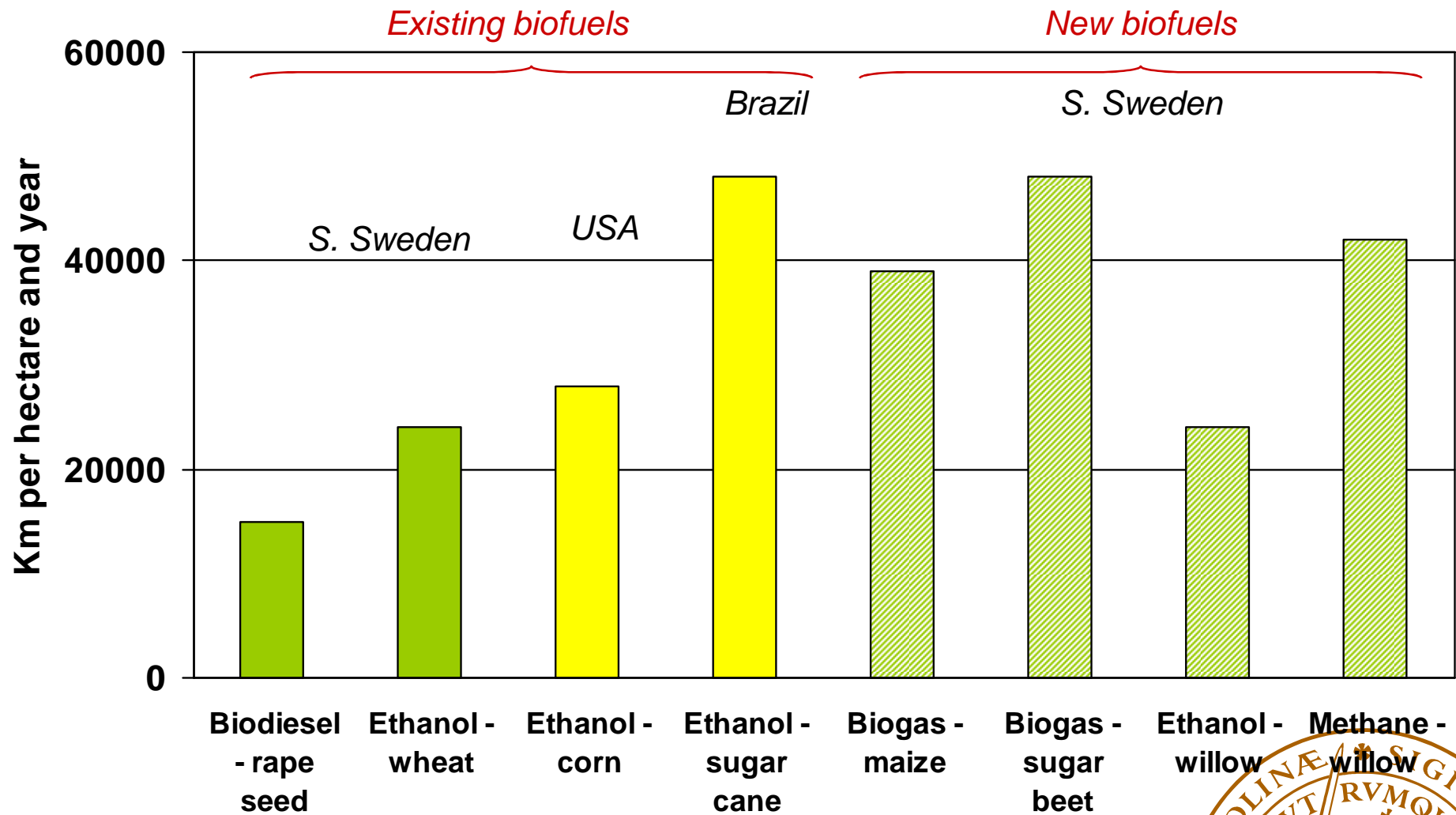


(Based on current conditions in Northern Europe, biomass-based energy input in biofuel plants, and economic allocation of by-products)

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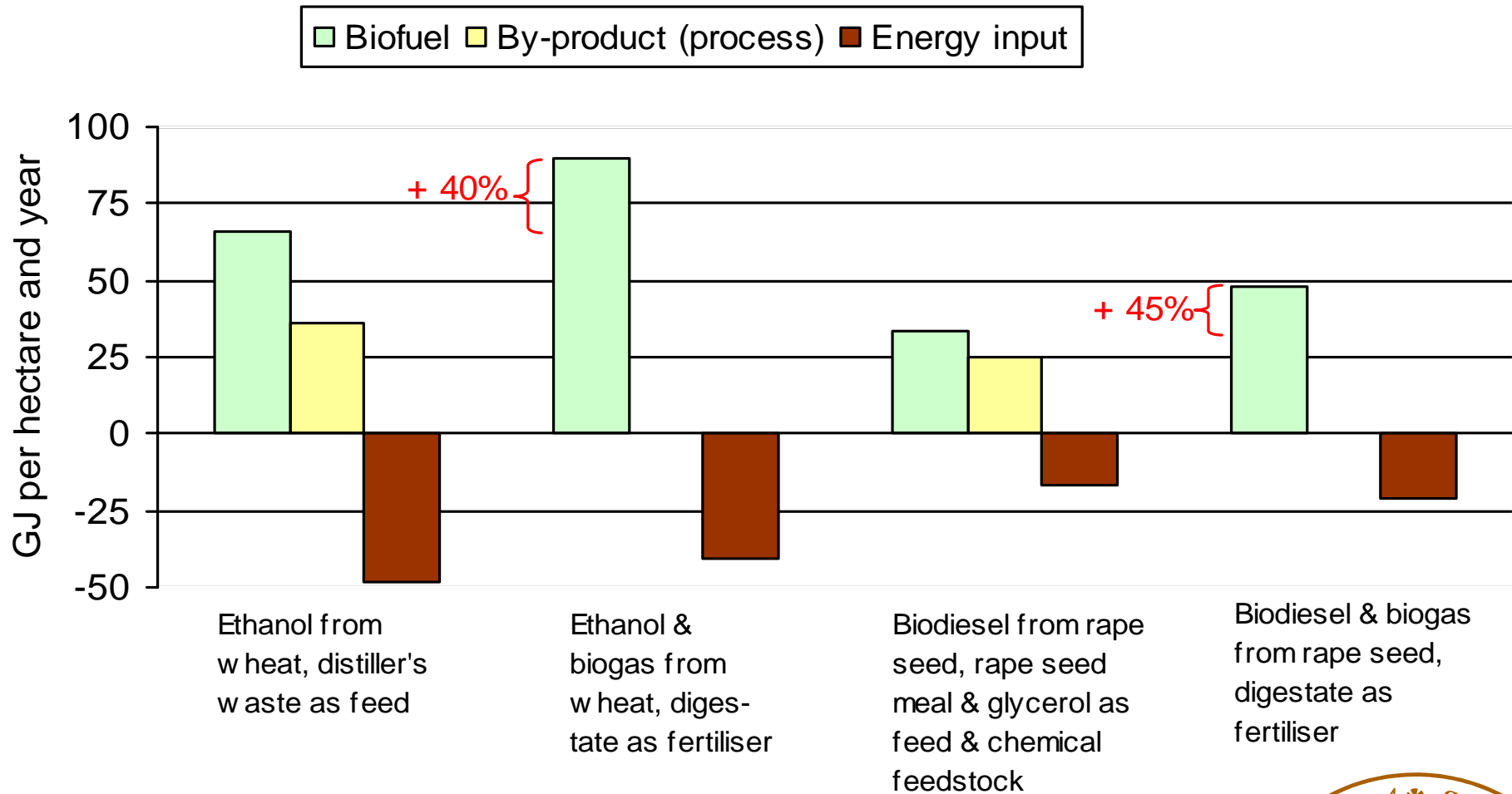
Driving distance per hectare and year



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Co-production of ethanol, biodiesel and biogas

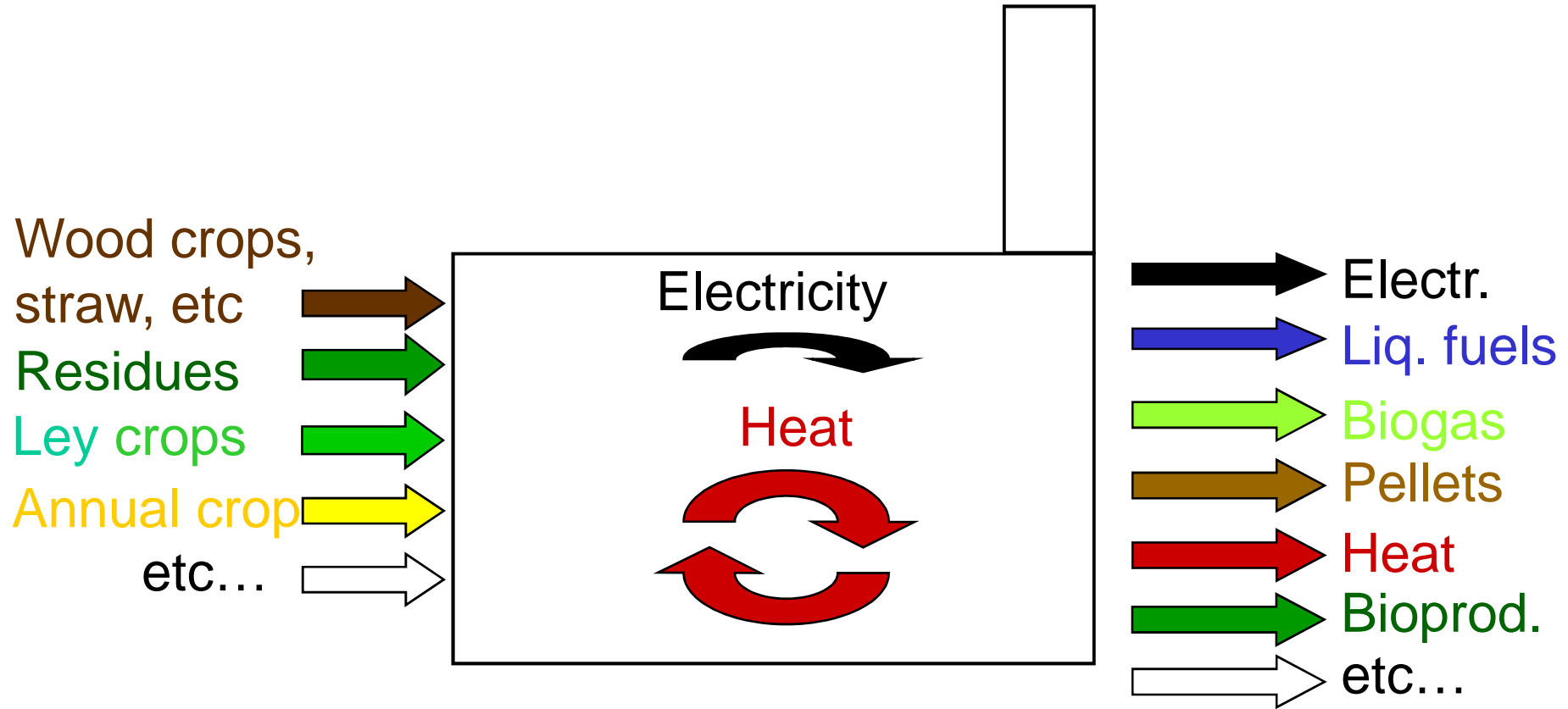


(Cultivation in northern Europe on average arable land, by-products from cultivation is not included)

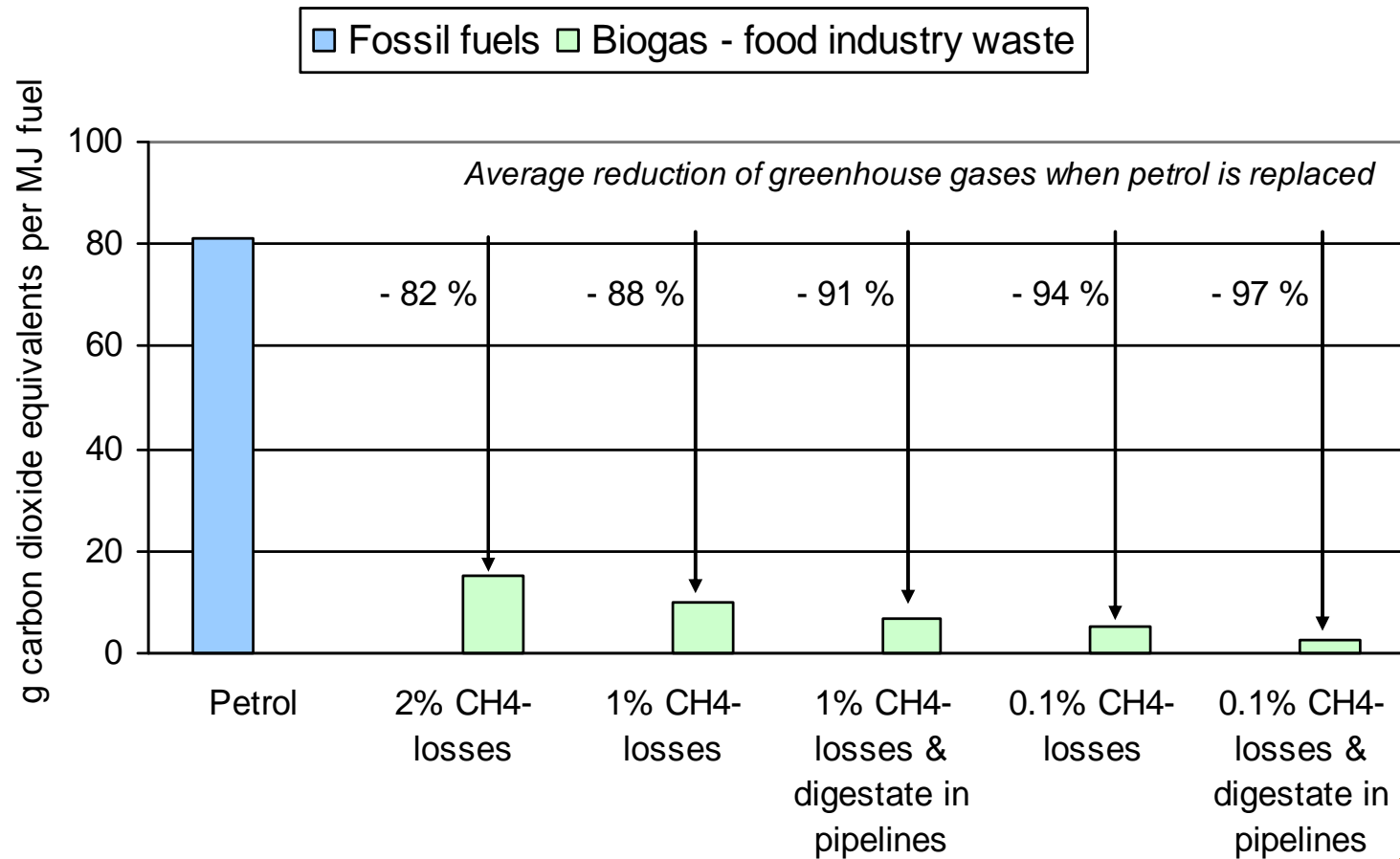
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The future = "Optimized bio-refinery"!



Emissions of greenhouse gases (*well-to-wheel*) - *Improved biogas systems*

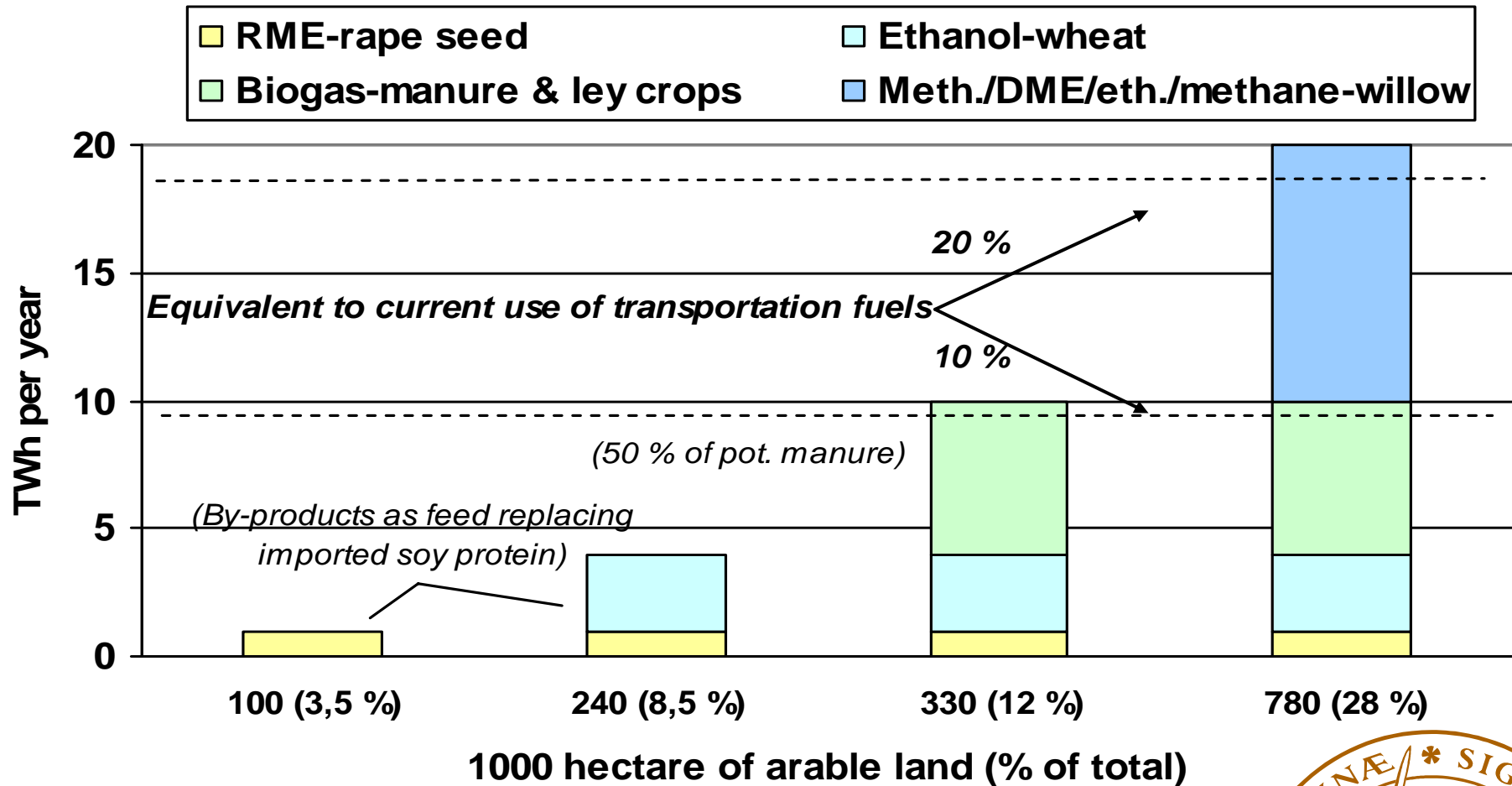


(Based on current conditions in Sweden)

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Resource efficient domestic biofuel production in Swedish agriculture – one example



Conclusions

- "All" analysed biofuel systems can be motivated from a broad systems perspective – however, some systems only up to a limited level (*e.g. ethanol from grain and RME from rape seed which require an efficient utilisation of by-products, e.g. as animal protein feed*)
- High prices of food crops and an increased demand of land and biomass resources will increase the interest of utilising high yielding crops and efficient conversions processes, together with organic waste materials not utilised today.
- Thus, biogas systems and the "second generation" biofuels based on lignocellulose, together with bio-refinery solutions, stands out as the most promising alternatives in a future expansion of biofuels in Europe.
- Production systems of biofuels must have a proofed, overall good environmental performance (*certification schemes will be implemented*), otherwise risk of a back-clash (*thus, the GHG-benefits of biogas systems can act as an important driving force, BUT minimizing the losses of methane will be crucial!*)

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