# The climate benefit of Swedish ethanol- present and prospective performance

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# Background

- Current 1G ethanol production is based on wheat where DDGS is used as protein feed, but this market is limited
- The wheat is mainly cultivated on open farmland but a future expansion may take place on excess grassland
- New feedstock including straw, short rotation woody crops, and forest biomass is estimated to increase in the future where the production of 1G and 2G ethanol could be integrated
- The purpose of this study is to show the implications on the GHG performance of an expanded ethanol production in Sweden

# Swedish 1G ethanol production system

**Energy input** | **Energy output**

*(GJ / hectare)*

*Seed, agro-chemicals, diesel, machinery, etc.* → *(15)* → **Wheat cultivation** → *(80)* → *Straw (60% harvest)*

⇩ *(120 - grain)*

*Diesel, vehicles, etc.* → *(1)* → **Transport**

⇩

*Heat, steam & electricity from forest fuels, etc.* → *(36)* → **Ethanol production** → *(40)* → *DDGS*

**Ethanol production** → *(66)* → *Ethanol*

**Pål Börjesson, Environmental & Energy Systems Studies, Lund University**

# Swedish 1G ethanol production system

Cultivation
*2.3 kg wheat*

1.6 kg straw → *Replacement of 1.4 kg wood fuels*

Transport

Processing

0.8 kg distiller's waste → *Replacement of 0.5 kg soy meal & 0.3 kg barley*

1 litre ethanol

*Replacement of 0.68 l petrol*

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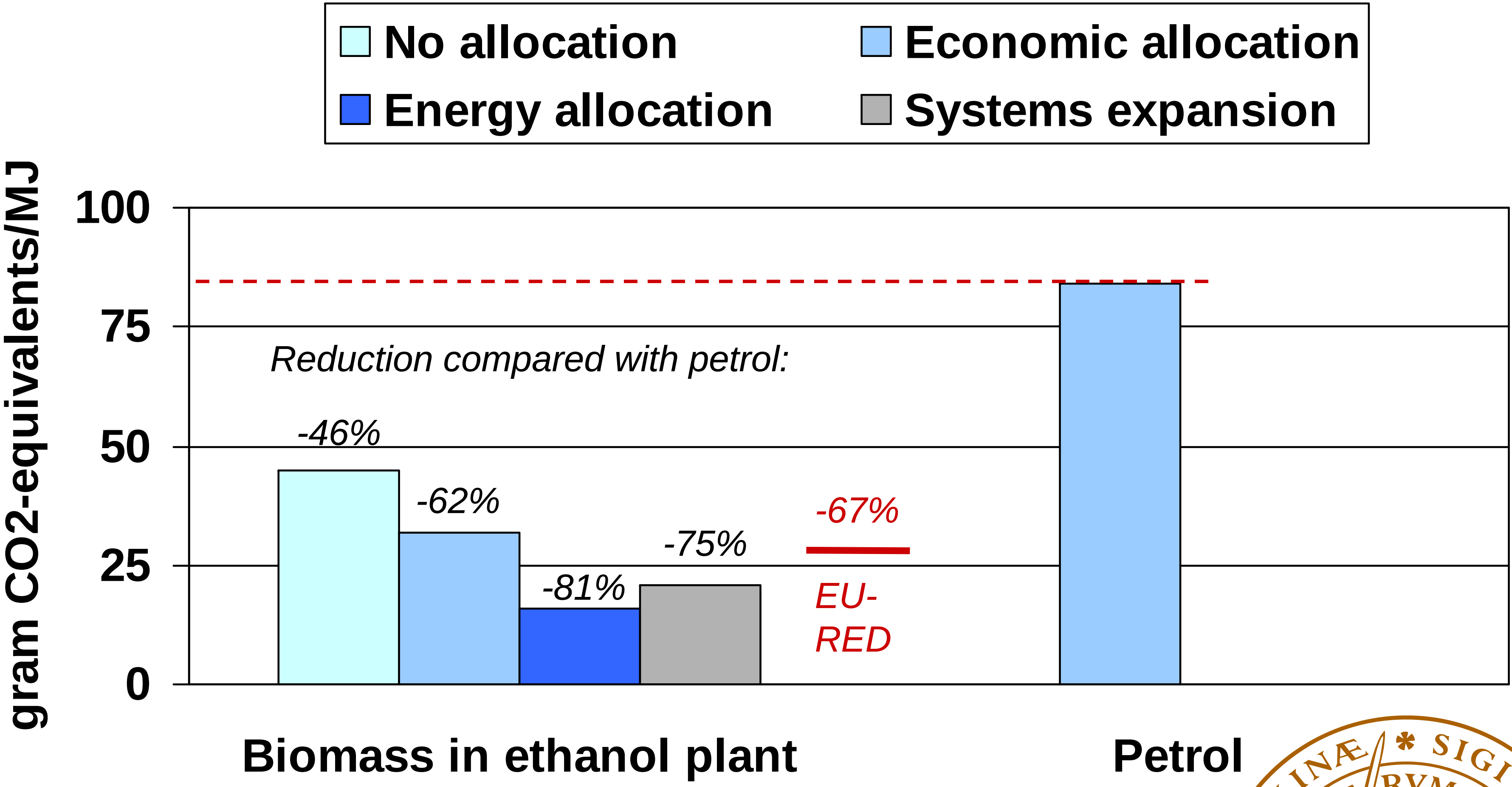
# Emissions of greenhouse gases
## *- per MJ ethanol*




*Ref. Börjesson (2009), Applied Energy (86) 589-594*

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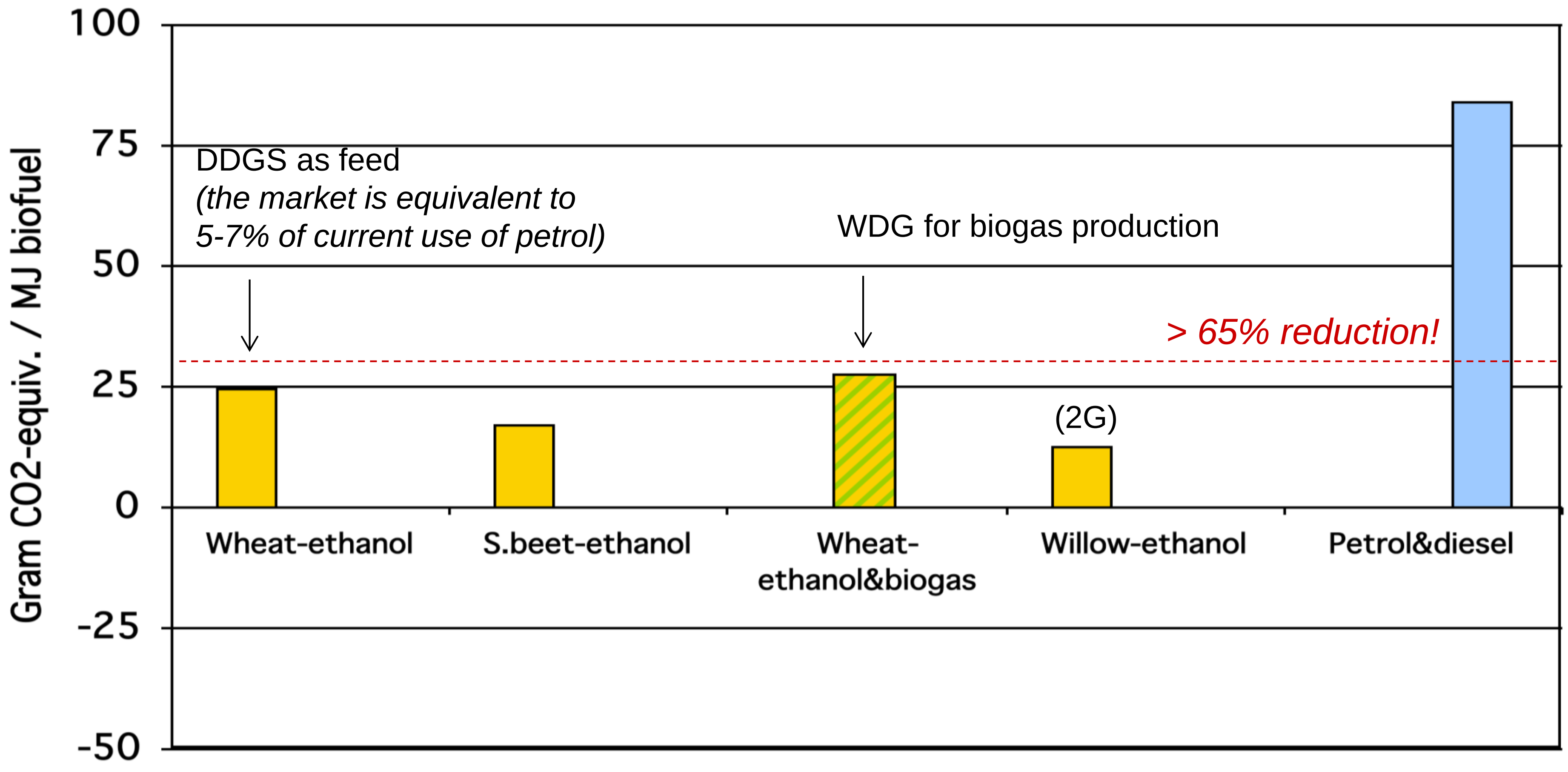
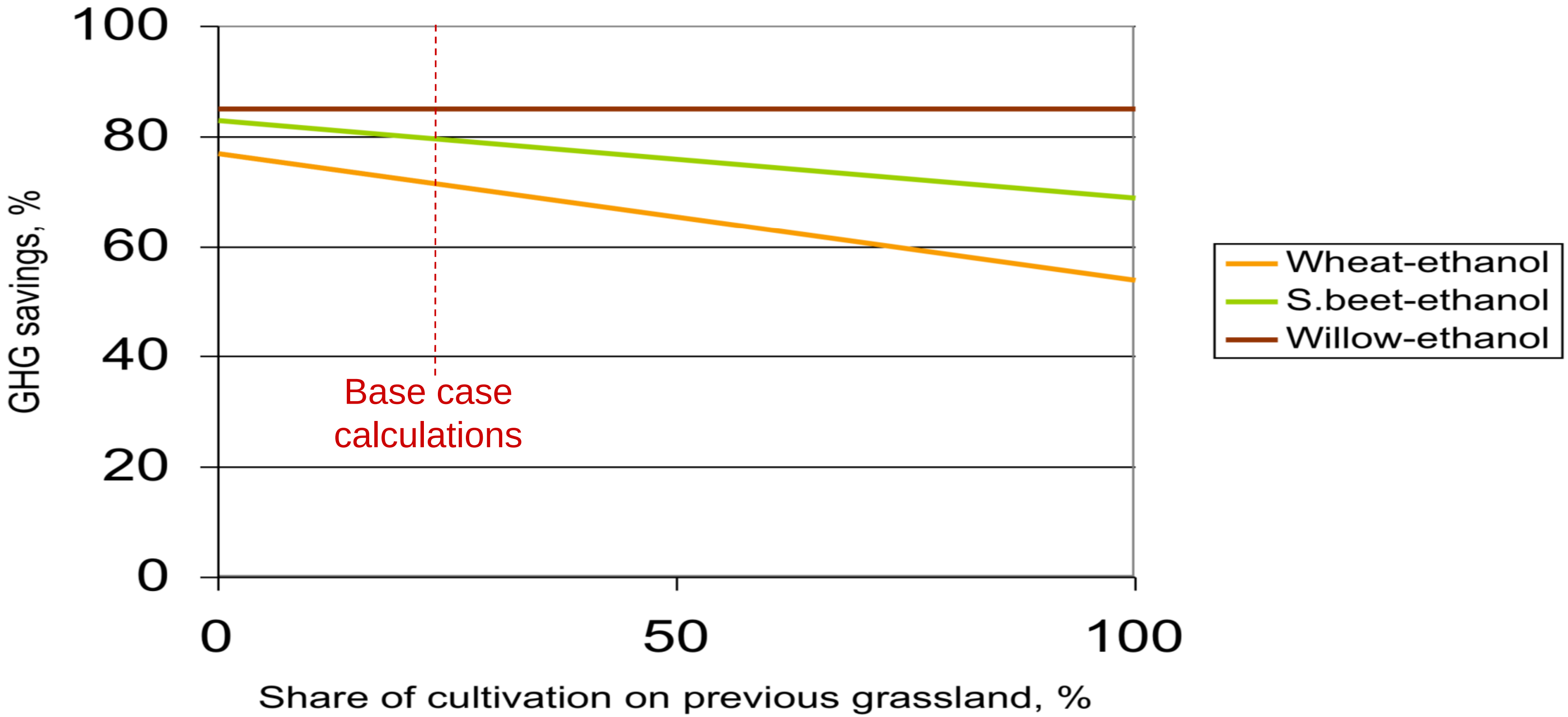
# GHG performance of crop-based ethanol (incl. dLUC)*



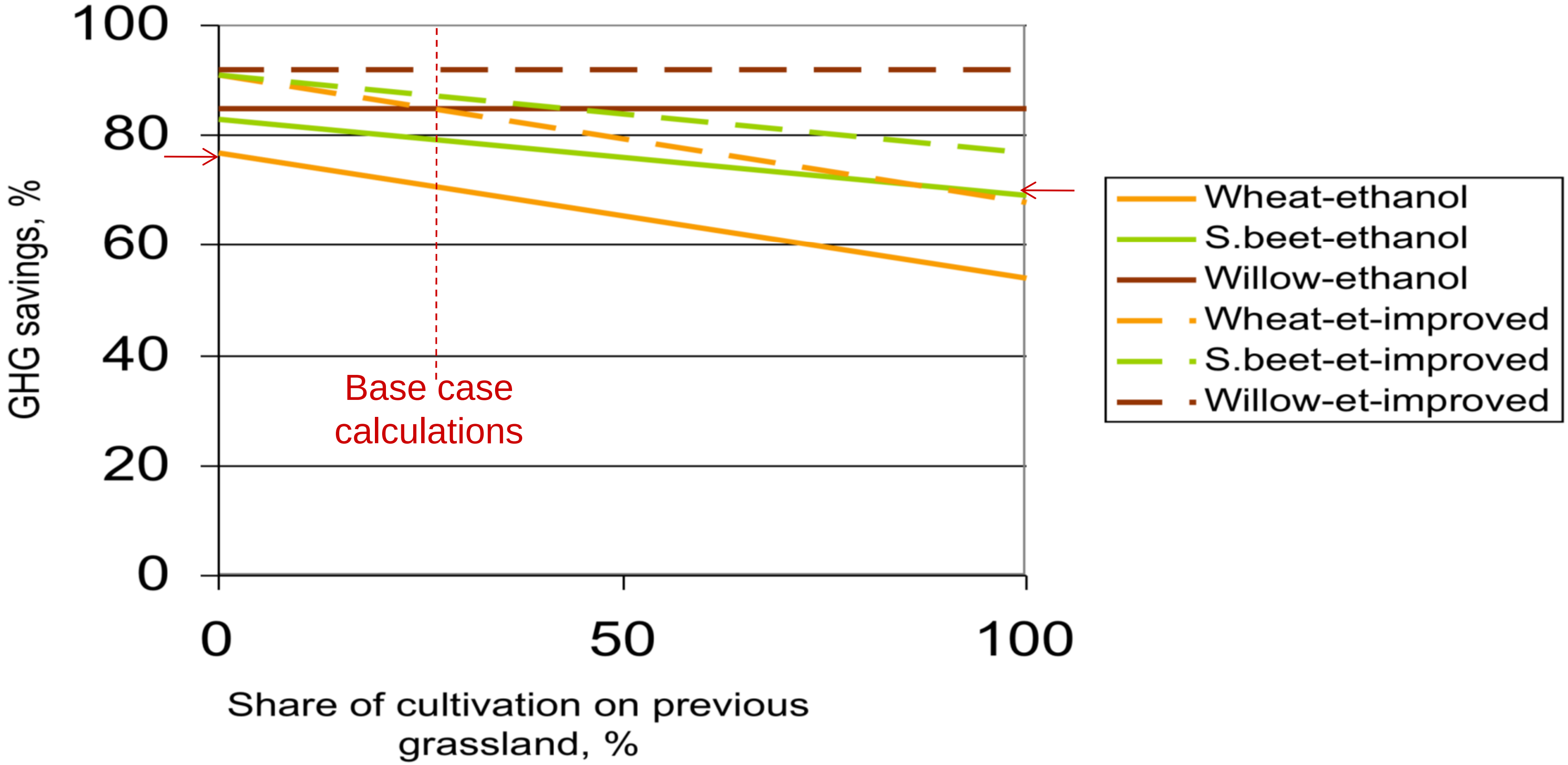

*Ref. Börjesson & Tufvesson (2011), J Clean Prod (19) 108-120*
** Based on system expansion and excluding straw. Cultivation on 25% previous grassland*

# GHG savings and direct land use changes (dLUC)*



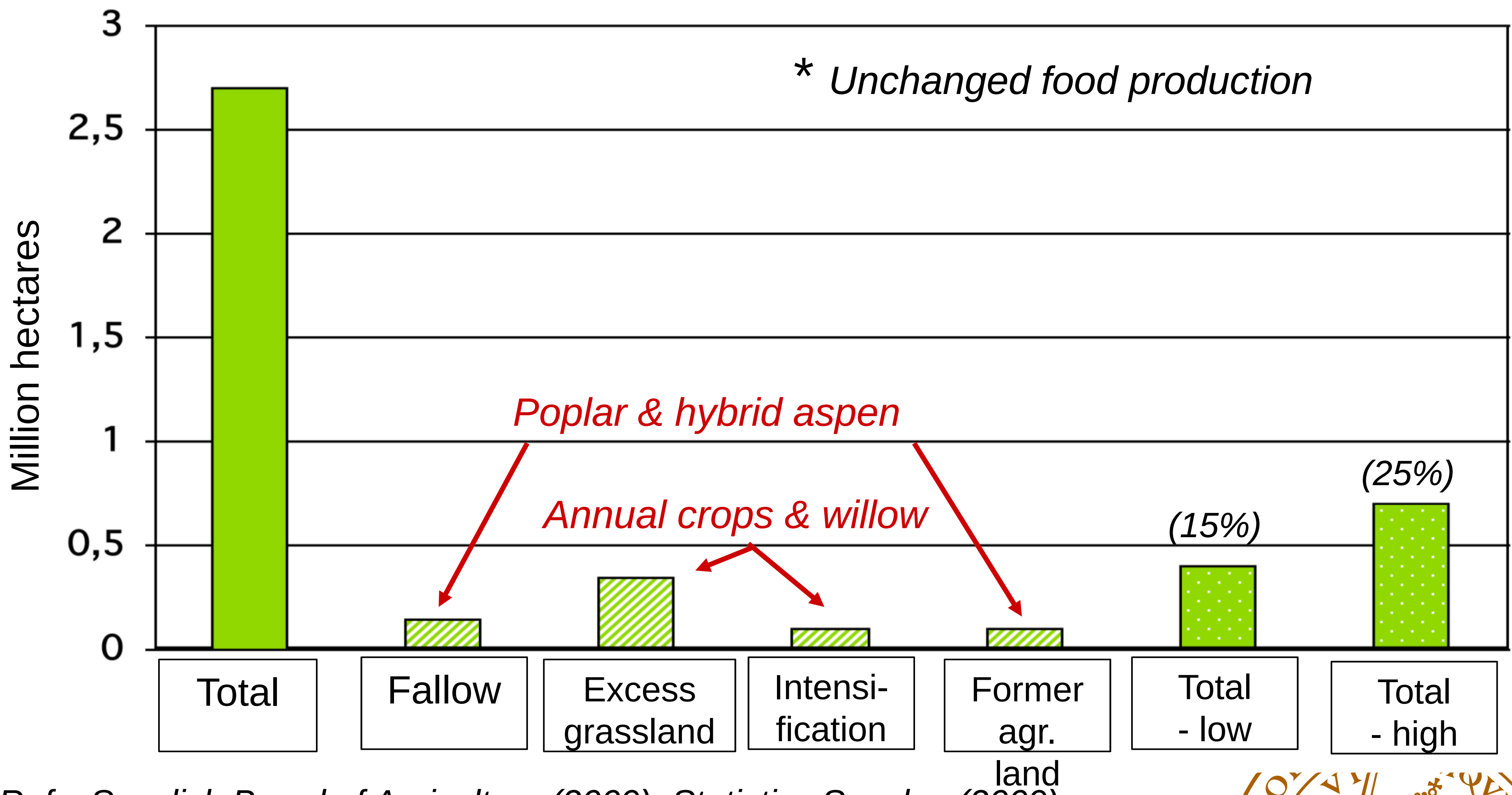

*Ref. Börjesson & Tufvesson (2011), J Clean Prod (19) 108-120*
** Based on system expansion and excluding straw.*

# GHG savings, dLUC and GHG free N fertilisers*




*Ref. Börjesson & Tufvesson (2011), J Clean Prod (19) 108-120*
*& Ahlgren et al. (2008), Bioresource Technology (99) 8034-8041*
** Based on system expansion and excluding straw.*

# Potential of arable land for bioenergy production
## *– dynamic effects in Swedish agriculture**




*Refs. Swedish Board of Agriculture (2009); Statistics Sweden (2009)*

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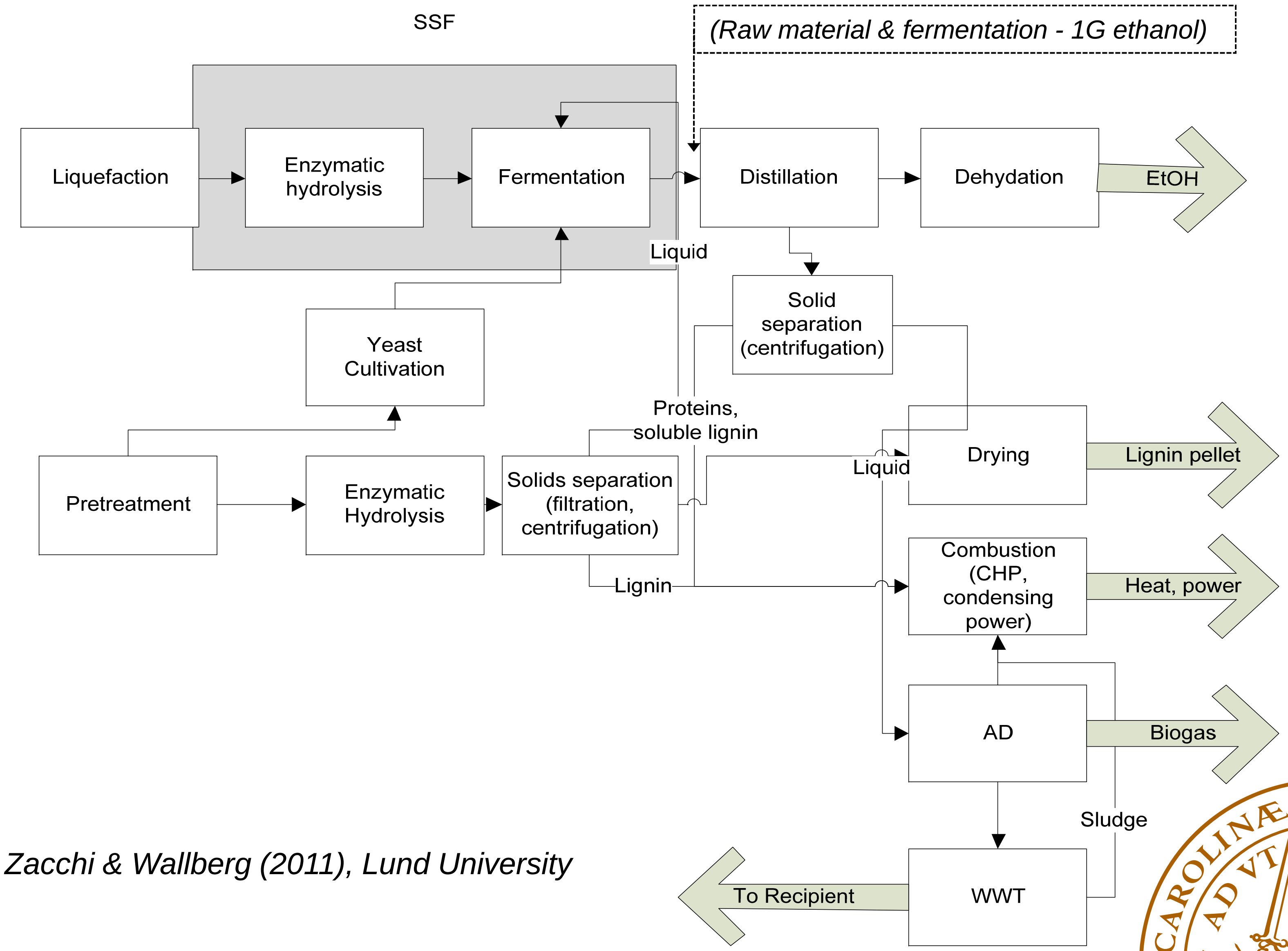
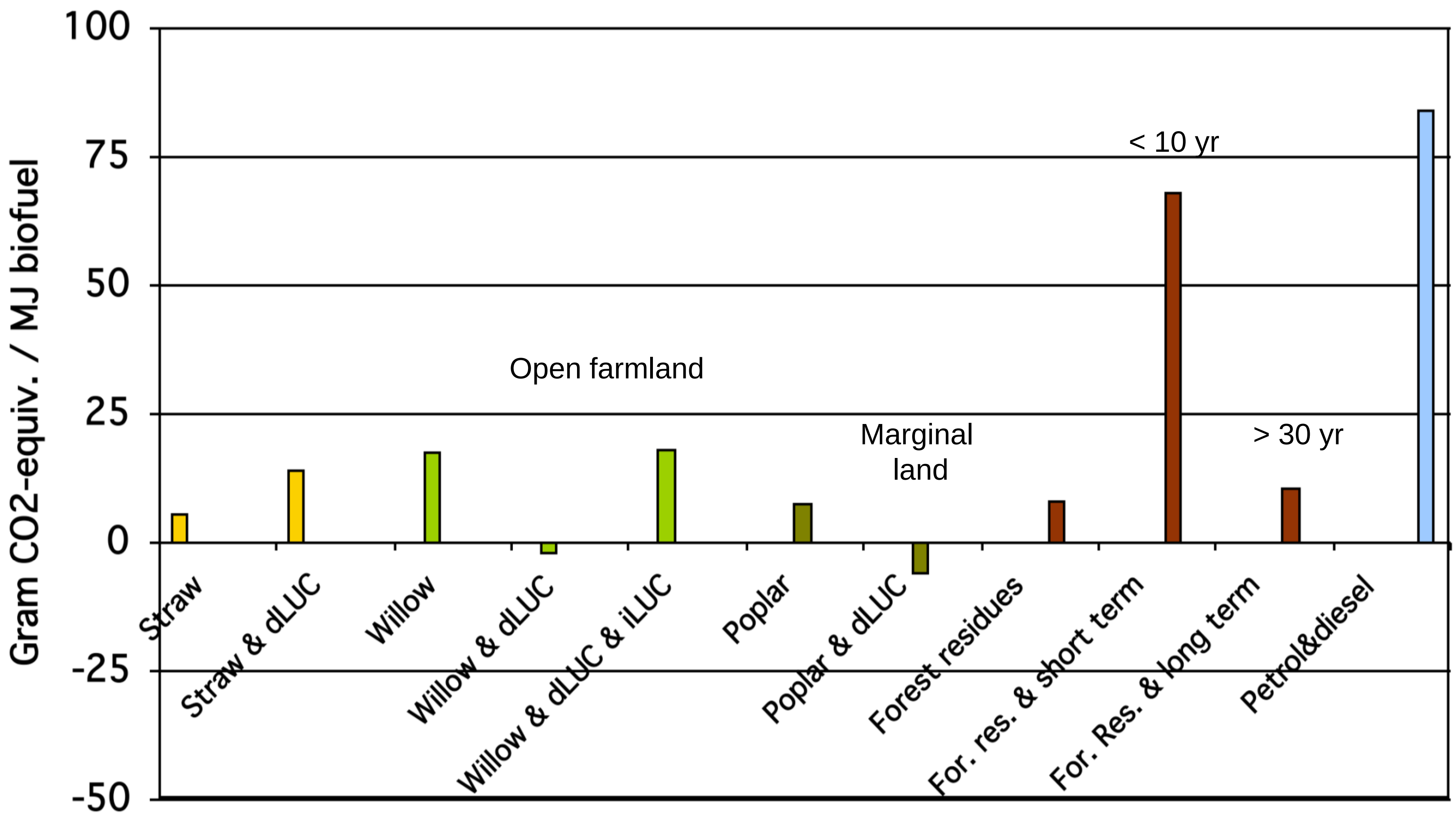
# Developed 2G ethanol production system




*Ref. Zacchi & Wallberg (2011), Lund University*

# GHG performance of 2G ethanol incl. dLUC & iLUC*




** The iLUC factor is assumed to be 20 g CO2-equiv. / MJ*

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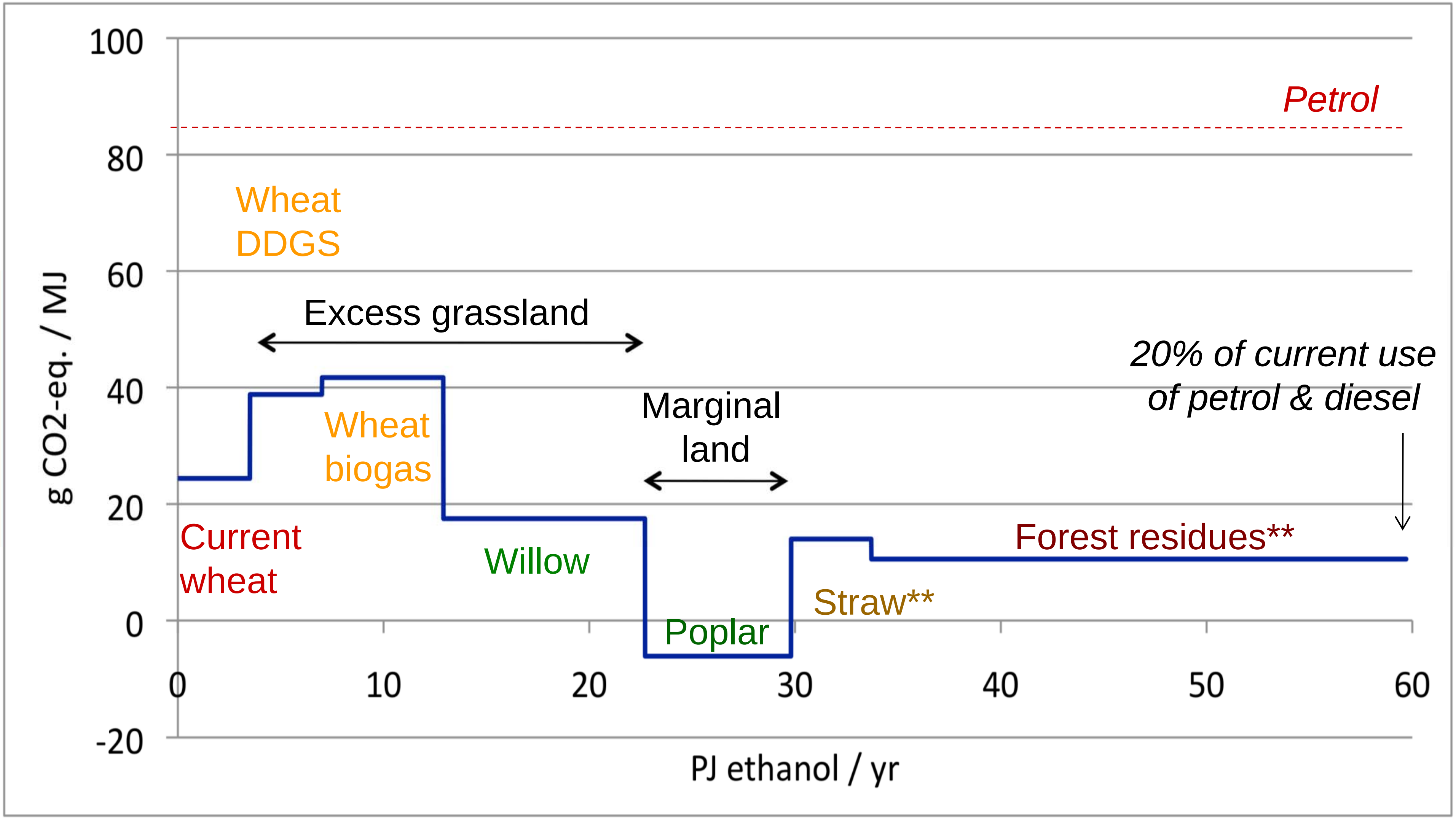
# Expanded ethanol production and GHG performance*




** Based on system expansion, incl. dLUC; ** 50% of available, unused potential*

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# Conclusions

- An expansion of 1G ethanol equivalent to 7% of current fossil vehicle fuels will increase GHG emissions from around 25 g/MJ to around 40 g/MJ due to dLUC during a transition period, but not affect current food and feed production (thus no iLUC)
- Improved production technologies (e.g. GHG free N fertilisers) could almost counteract these negative dLUC
- Willow-based 2G ethanol on excess grassland, instead of 1G ethanol, will result in GHG emissions of around 17 g/MJ
- Poplar-based 2G ethanol on abandoned arable land could result in "negative" GHG emissions (-5 g/MJ) due to positive dLUC during a transition period (30-50 years)

# Conclusions

- Straw-based 2G ethanol equivalent to current amount of 1G ethanol will give GHG emissions of around 15 g/MJ (incl. dLUC)
- Forest residue-based 2G ethanol will result in GHG emissions of around 10 g/MJ in a mid- and long-term perspective (> 30 years), but higher emissions during an initial phase (< 10 years)
- Swedish ethanol production could expand equivalent to 20% of current use of fossil vehicle fuels having an average GHG performance of roughly 15 g/MJ, in a 30 year perspective
- Thus, it is motivated to use a certain share of an allowed GHG emissions space in relation to GHG targets for short-term GHG emissions in the development of long-term sustainable bioenergy system, such as “good” ethanol systems