1st or 2nd generation bioethanol
- Impacts of technology integration and on feed production and land use

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Outline

- Integration – what is it and what is it not?
- A simulation study on technology options in converting wheat to ethanol
  - Terminology and key assumptions
  - Results
  - Conclusions
- Perspective

What is, and what is not integration?

manure

meat

milk

grain

Technology integration
(one dimension)

straw

power

heat

What is, an ion?

Sectoral integration (another dimension)

Another option for sectoral integration

manure

meat

milk

DDGS

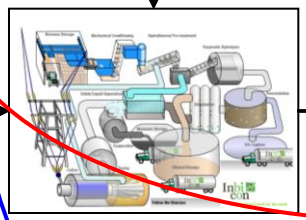
molasses

Grain

power

heat

Further technology integration (one dimension)



biofuel

ethanol

Straw

CO2

A simulation study on different technology options for converting biomass to ethanol

Purpose:

- Explore the impact on energy loss, feed production and land use of different technology options in the conversion of agricultural produce into ethanol

Case:

- Winter wheat in Northern Europe

Key assumptions:

- Area is the operational unit.
  - 1 ha is the starting point of the study, not x kg of resource, as the supply of e.g. straw cannot be changed without changing the supply of grain.
- ”There is no such thing as a free lunch”.
  - There are no ”free” resources. There’s always a cost associated with the use of a resource.
- Grain is not considered as an energy commodity as it is not legal according to Danish law to use grain in public heat production.
  - The energy value of grain is not it’s LHV but the energy required to produce it.
- We do not consider economy.
  - A very important issue, but not the scope of this study.

Terminology and scenarios

- **1st generation bioethanol:** Fermentation of sugar or starch (sugar cane, corn, cereal grain).
- **2nd generation bioethanol:** Fermentation of lignocellulose (wood, straw, grass, stover).

- **Integrated scenario:** Biorefinery is integrated with CHP via steam bleeding.
- **Not integrated scenario:** Steam is provided with natural gas boiler.

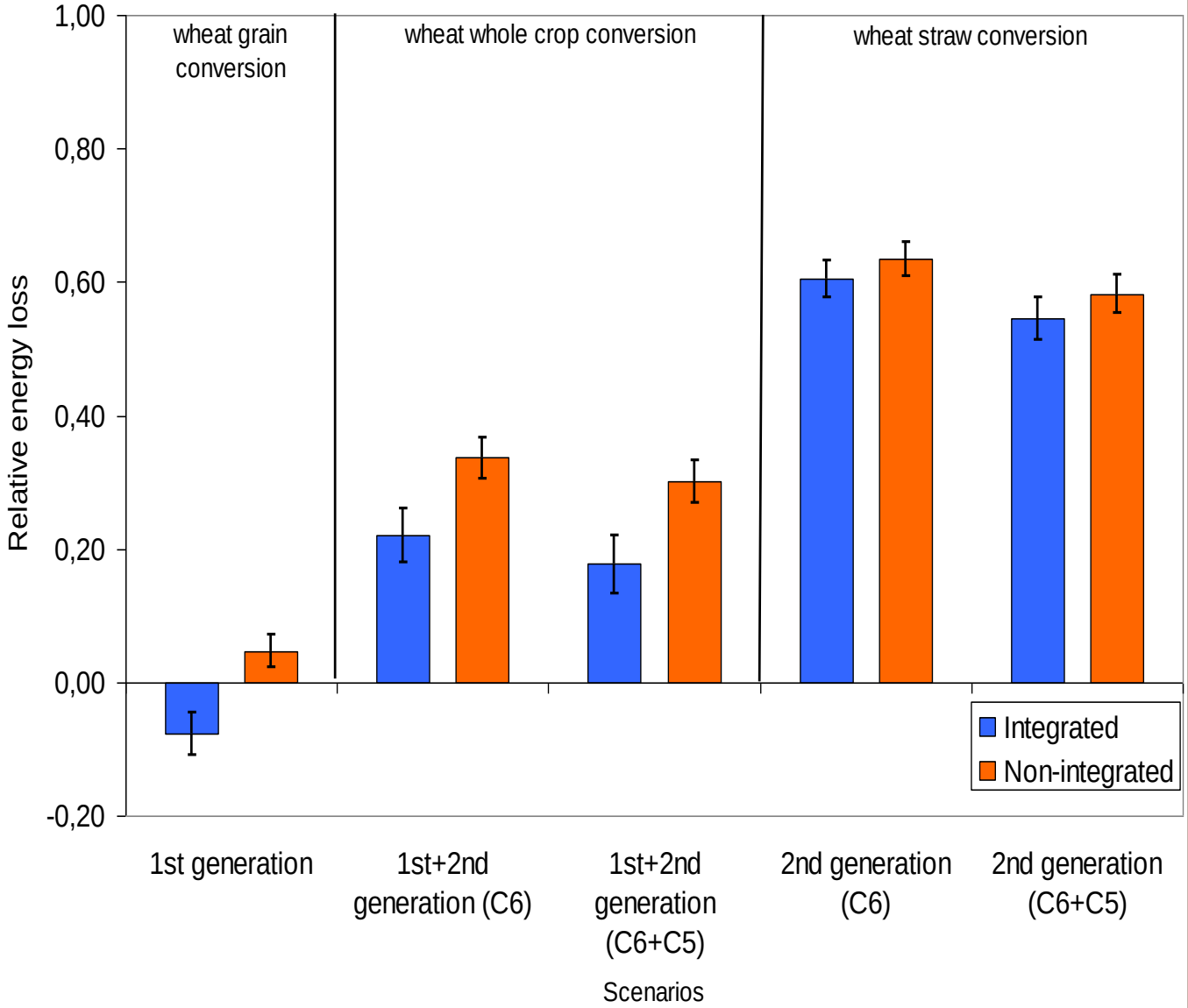
- **1st generation:** Grain to ethanol and protein rich DDGS, straw to CHP.
- **1st + 2nd generation (C6):** Grain and straw to ethanol, DDGS, energy rich C5-molasses and solid lignin rich biofuel. Only C6 sugars (hexose) converted.
- **1st + 2nd generation (C6+C5):** As above but C6 and C5 sugars (pentose) converted.
- **2nd generation (C6):** Grain to feed and straw to ethanol, C5-molasses and solid biofuel. C6 sugars converted.
- **2nd generation (C6+C5):** As above but C6 and C5 sugars converted.

Energy loss

Negative energy loss in 1st generation is not a violation of the 1st law. A feed commodity is trans-formed into an energy commodity.

High energy losses in 2nd generation. An energy commodity is transformed into other energy commodities and feed.

Technology integration reduces energy loss in all scenarios



Benefit of technology integration

Net energy cumulated in the system:

Mass flow from sta mi re pr en

Stage 1:
Solar energy i
boosted with
fertilizers, pes
management,
improved crop

Stage 2:
A feed commodity is ”upgraded” to energy

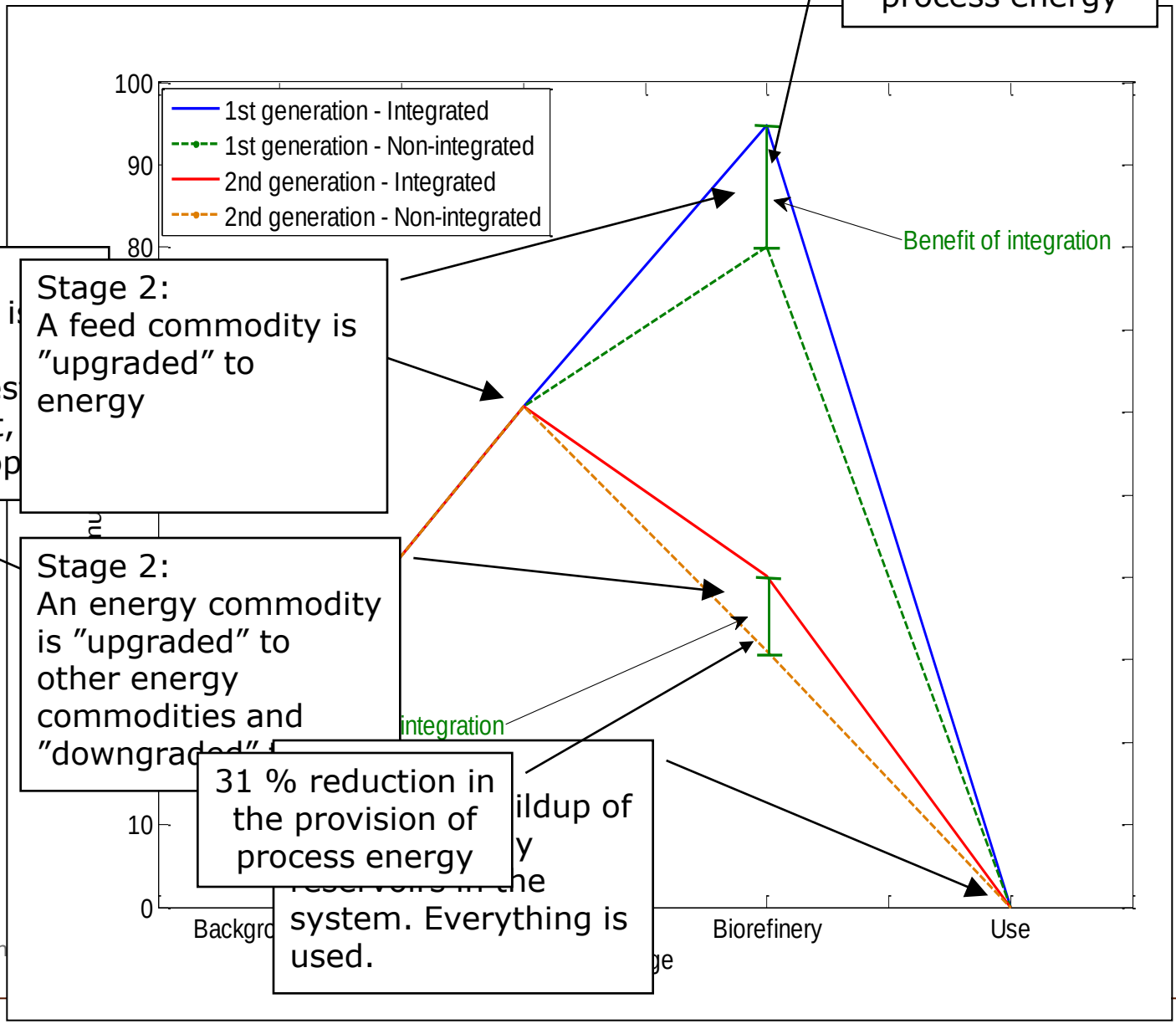
Stage 0:
Sun and earth provides a certain level of production without human intervention.

Stage 2:
An energy commodity is ”upgraded” to other energy commodities and ”downgrad

31 % reduction in the provision of process energy

ildup of
y
he
system. Everything is used.

34 % reduction in the provision of process energy



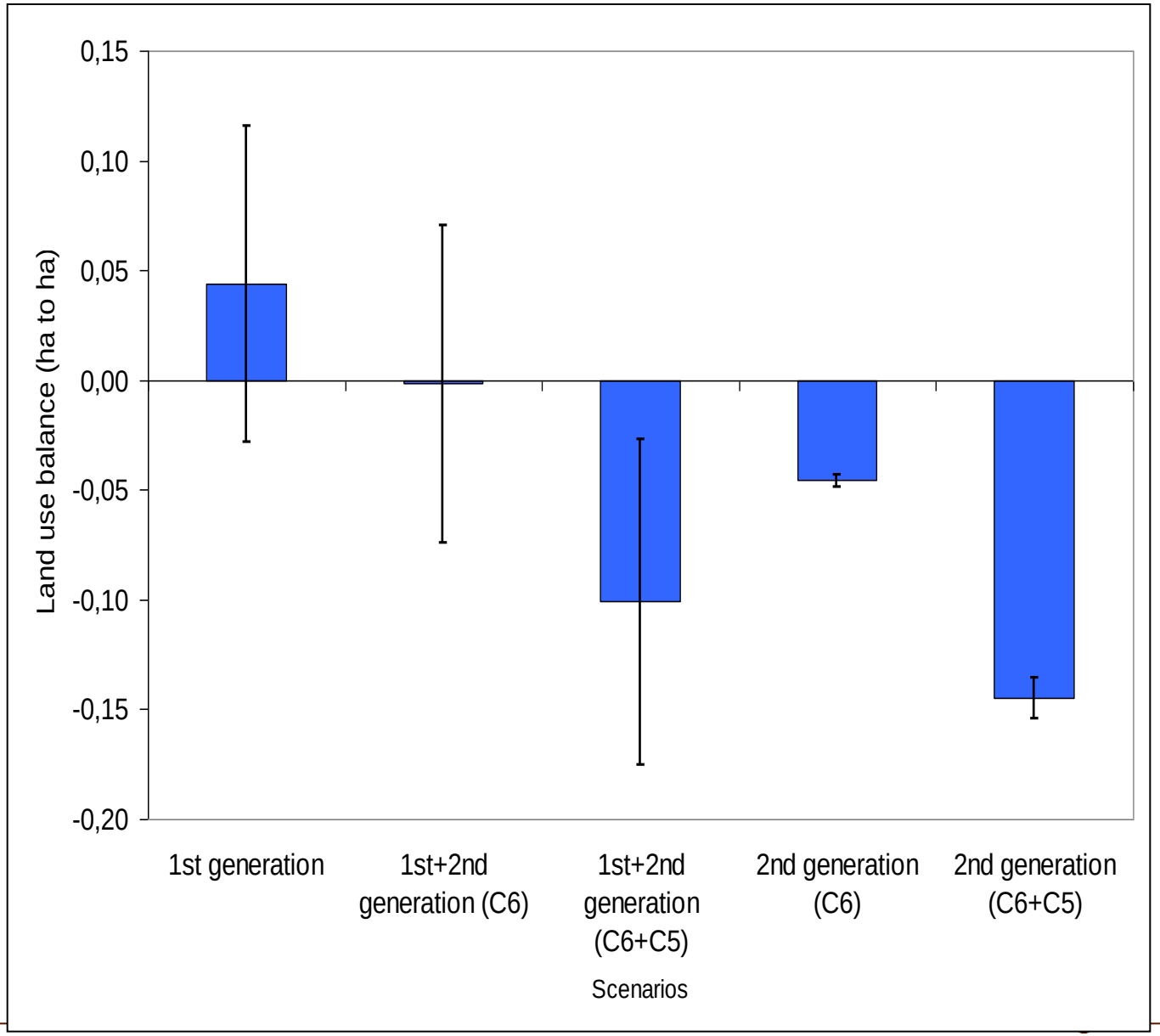
Impacts on land use

Through conversion grain is transformed from energy rich feed into protein rich feed (DDGS) that displaces soy bean.

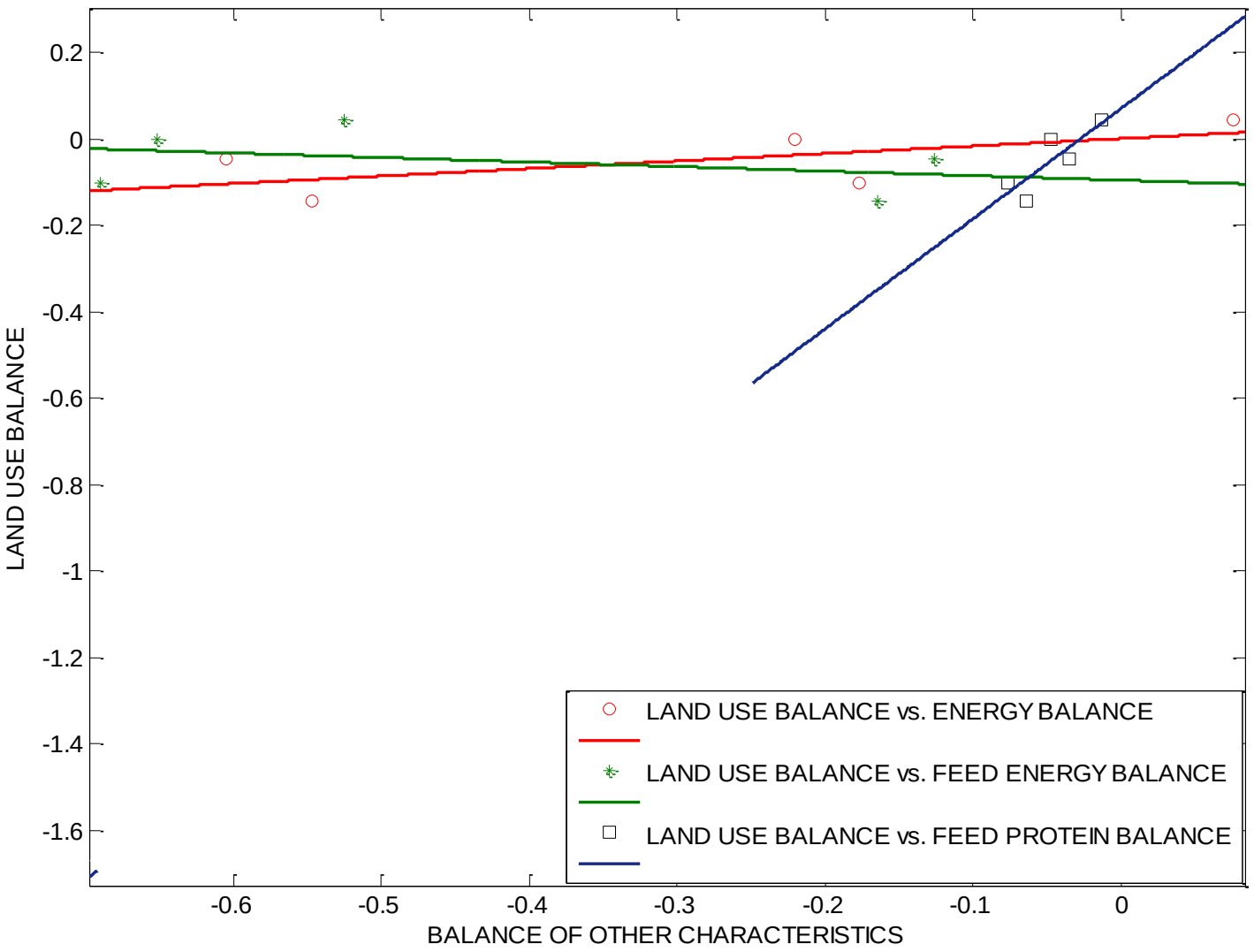
Straw is transformed from low enery feed into medium energy feed.

A North European wheat field produces more than double in feed units than a US soy field

Soy bean yields are much more volatile wheat yields



Drivers of land use impacts

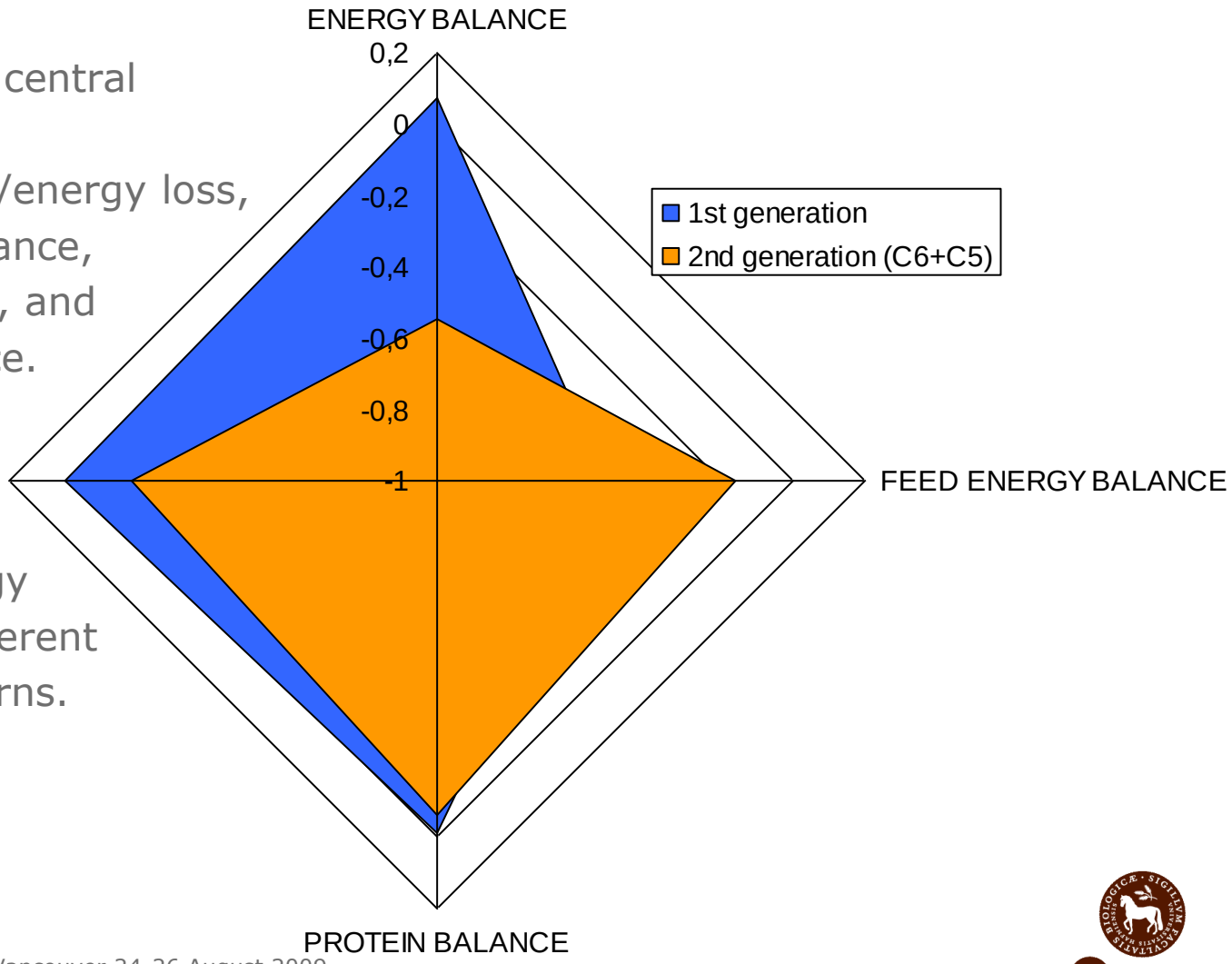


Multi characteristic evaluation

Evaluation on four central characteristics:

i) energy balance/energy loss,
ii) feed energy balance,
iii) protein balance, and
iv) land use balance.

Different technology options exhibit different performance patterns.



Conclusions and perspective

- Integrating biorefineries with CHP may reduce the cost of process energy provision with ~30 - 35 %.

- Different technology options exhibit different characteristics
  - 1st generation technologies has the lowest energy loss and the lowest loss of proteins
  - 2nd generation technologies has the lowest loss of feed energy

- Don't waste proteins
  - Plants put a lot of effort into producing them and they are crucial in agricultures role as food and feed provider.

- Analysis of bioenergy systems must include other characteristics than energy e.g. food production and land use, as the use of biomass inevitably is linked to the use of land.

- In optimising bioenergy systems the impact on land use is a very important parameter. The right system configuration may lead to reduced or not significantly increased pressure on land.

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Thank you for your attention!