Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

# Production of ammonia and nitrogen fertilizers based on biomass – research efforts in Sweden

Serina Ahlgren
Dep of Energy and Technology
Swedish University of Agricultural Sciences

$NH_3$ conference, Sacramento, 23-25 September 2013

# Outline of presentation

- Intro Sweden
- Studies of future production based on renewables:
  - Techno-economic studies
  - Life cycle assessment studies

# Sweden

- 9.4 million people
- 449 964 km² (approx. same size as state of California!)

# Sweden, land

3 % urban area
53 % forest
8% agriculture
9 % mire
10 % heathland, bare mountains
9 % water

# Sweden livestock

- 360 000 milk cows
- 180 000 beef cows
- 1.6 million swine
- 200 000 sheep
- 260 000 reindeers

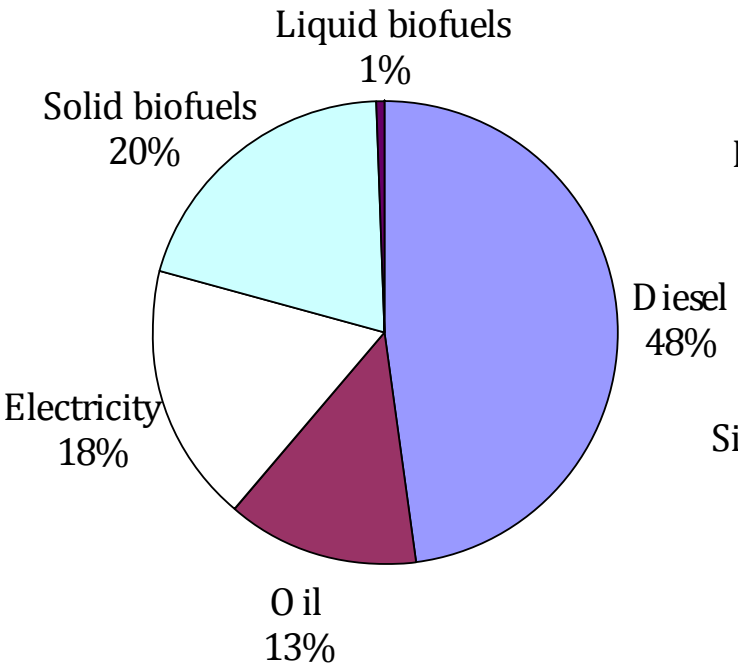
# Import of ammonia and N

At present: No production of ammonia in Sweden

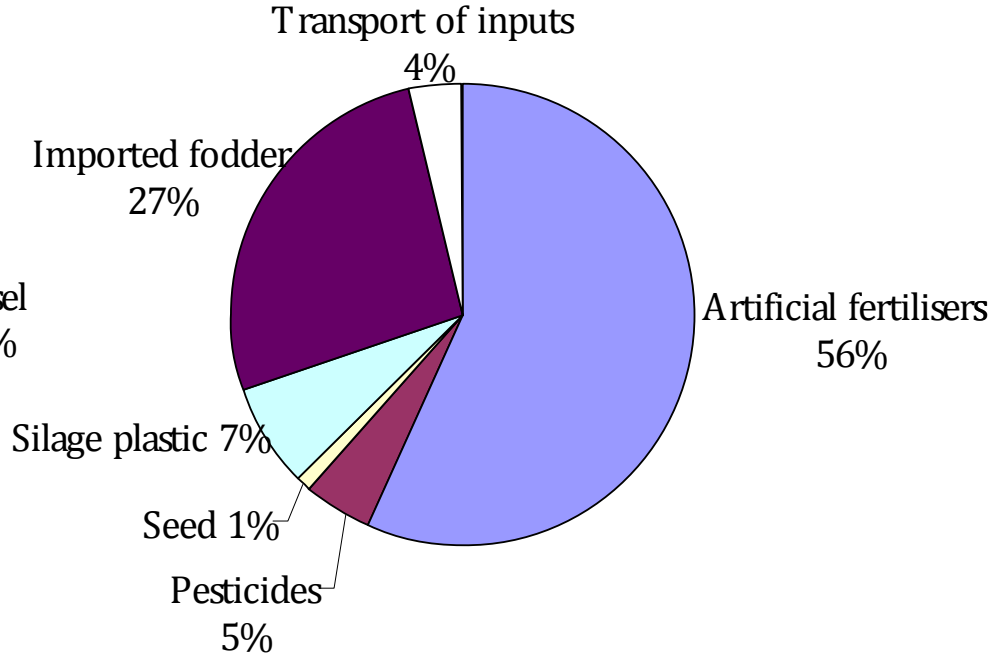
| Imports to Sweden during 2012, metric tons | |
|---|---|
| Anhydrous ammonia | 136 500 |
| Ammonia in water solution | 14 700 |
| Nitrogen in fertilizers (prilled calcium ammonium nitrate dominating) | 148 100 |

# Annual energy use in Swedish agriculture

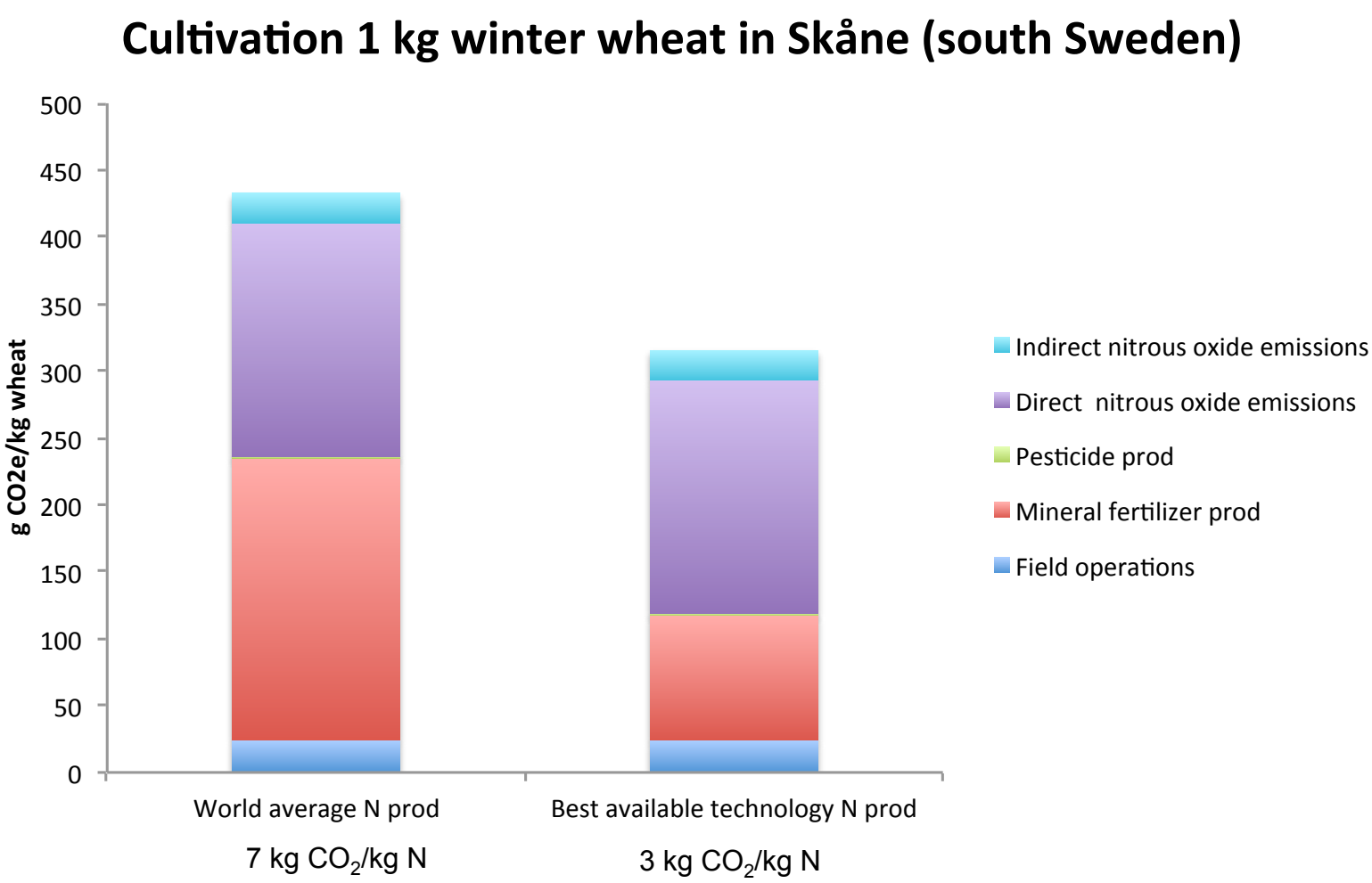
**Direct energy use 5.9 TWh**




**Indirect energy use 3.3 TWh**



# Nitrogen in crop GHG balance



# Studies of future production based on renewables. In co-operation with:

- Lund University, dep of chemical engineering
- University of Minnesota, West Central Research and Outreach Center, Morris

# Point of departure

N-fertilizers is a major contributor to fossil energy use and GHG in crop production

N-fertilizers are costly and the price fluctuates

Better utilization of renewable resources needed

# Techno-economics, conclusions

- Production of ammonia from non-fossil sources can be expensive (or, fossil fuel is cheap at the moment)

- Biomass gasification most promising alternative
  - economy-of-scale effects
  - lower feedstock cost

- Results will soon be published in **Environmental Progress & Sustainable Energy** (Wiley) "*Techno-Economic Assessment of Non-Fossil Ammonia Production"* Authors: Tunå, Hulteberg, Ahlgren

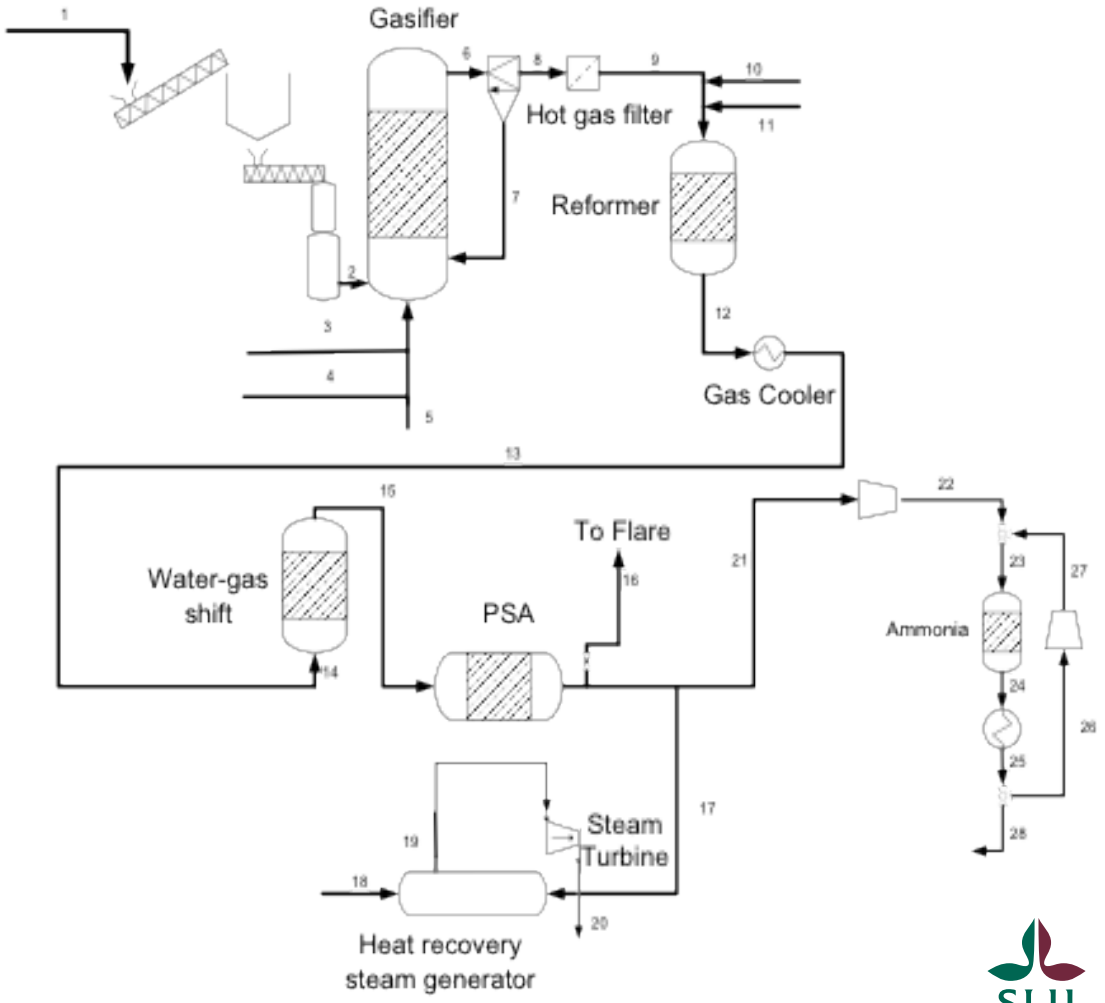
# Studied scenarios

- 3 MW Electrolysis
- 10 MW Electrolysis
- 5 MW Biogas from anaerobic digestion
- 10 MW Biogas from anaerobic digestion
- 50 MW Biomass gasification

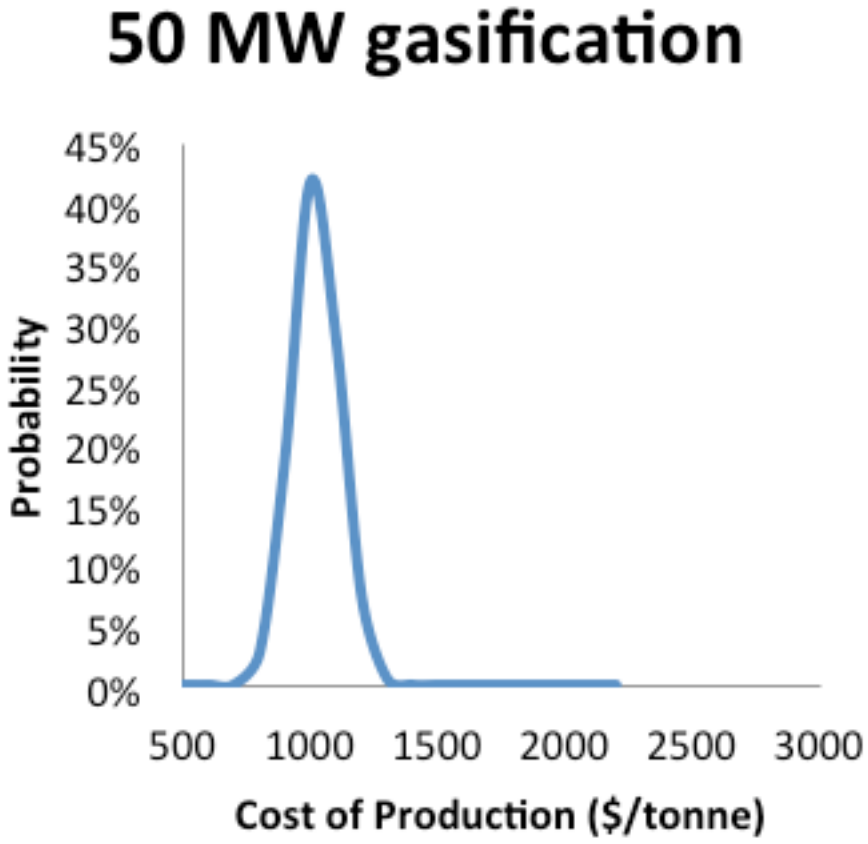
Modeling performed in Aspen Plus

# Biomass gasification - ammonia

- Circulating fluidized bed
- Steam reformer (800°C) + auto thermal reformer
- Ammonia synthesis modelled as three adiabatic reactors with recirculation. Pressure drop 3 bar, inlet temperature 427°C for each reactor
- Excess heat, for use in district heating grid, usable at levels down to 70 °C



# Biomass gasification - ammonia



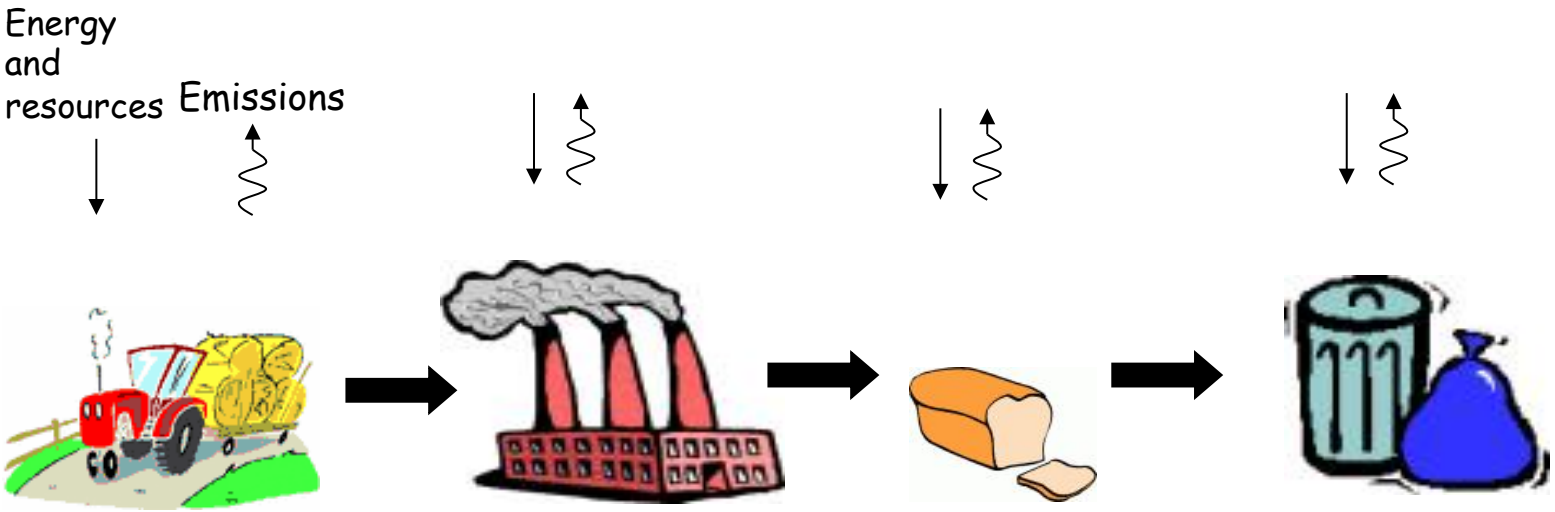

To the total bare-module cost, 18% contingency and 30% auxiliary added giving the overall investment cost

- Biomass 34 – 102 $/MWh
- Interest rate 5 – 12 %
- Investment cost ±30%

# Life cycle assessment

- Cradle to grave
- Cradle to gate

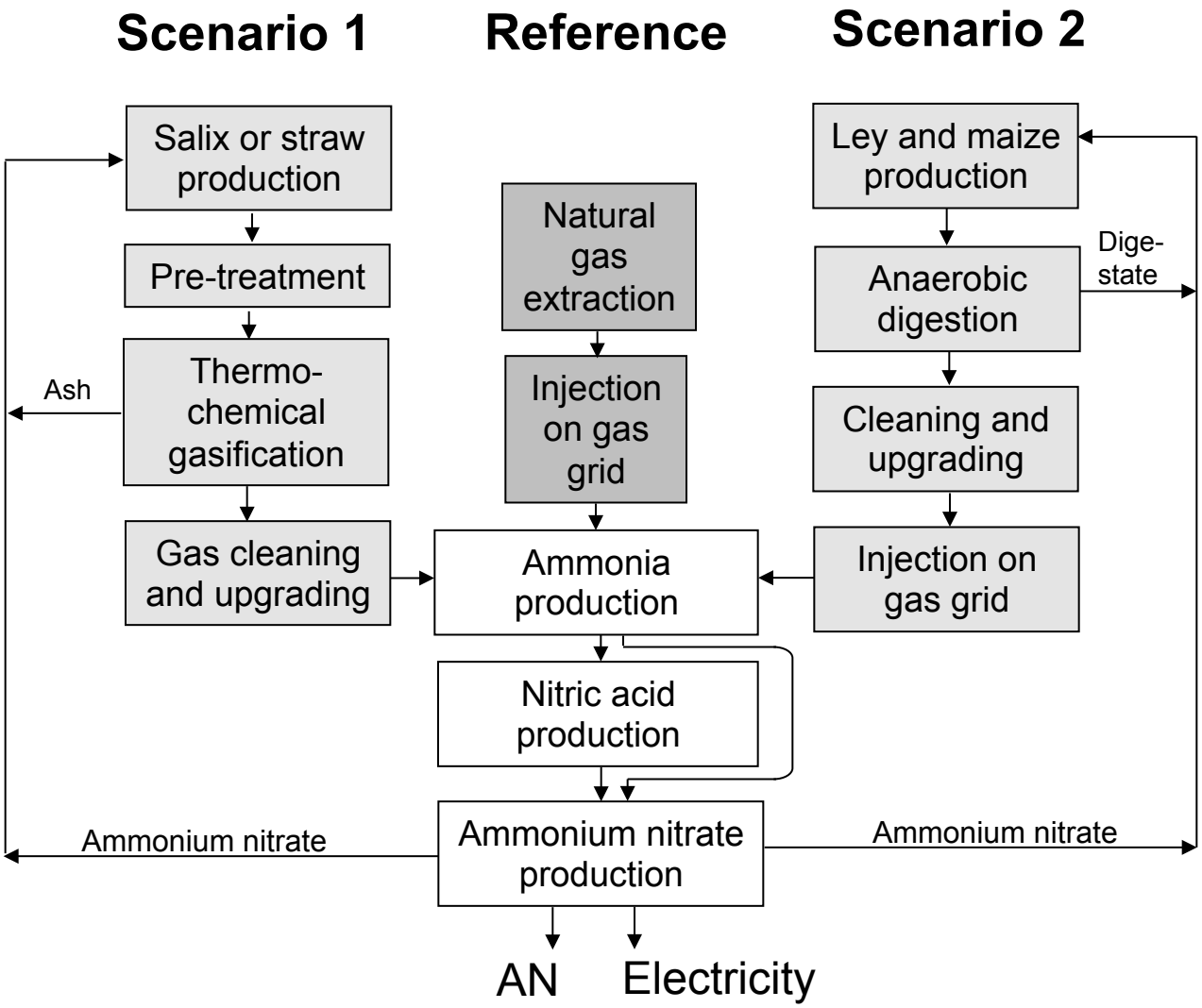
- Global warming potential
- Eutrophication
- Energy
- Land use
- etc



# Two types of LCA

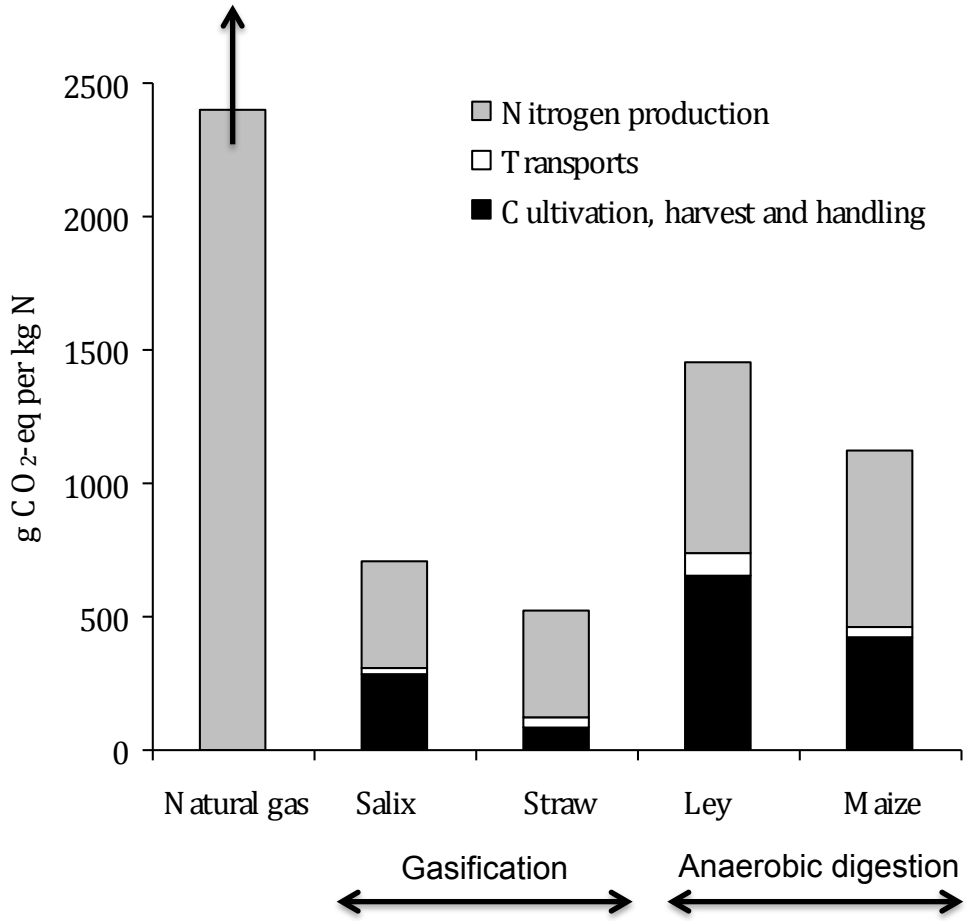
| **Attributional-LCA** | **Consequential-LCA** |
| --- | --- |
| Existing systems | Change-oriented |
| Average data | Marginal data |
| Allocation | System expansion |
| Only direct effects | Indirect (market induced) effects |

# ALCA – production of AN from renewables



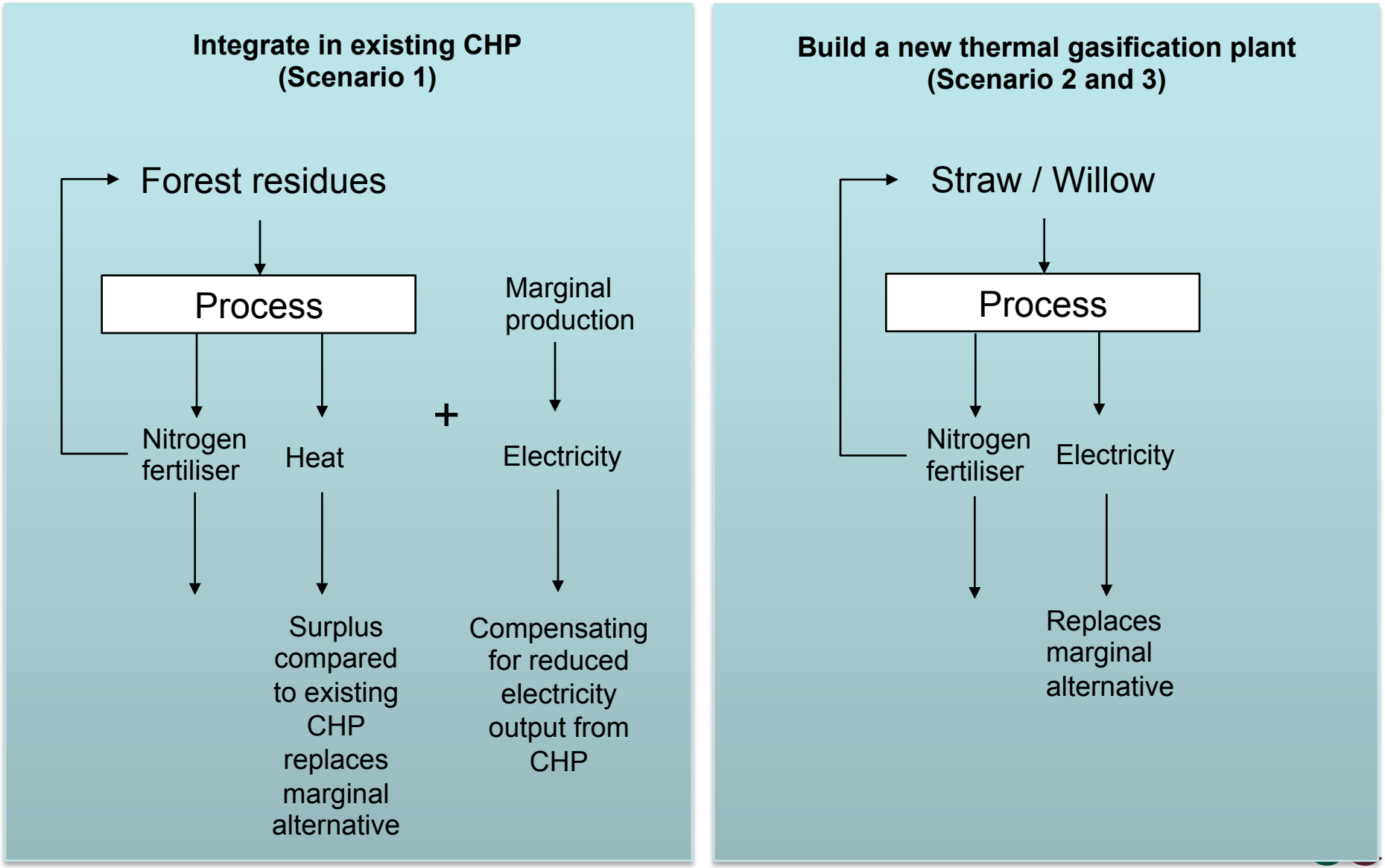

Salix (willow) in summer and winter

# ALCA results – production of AN from renewables

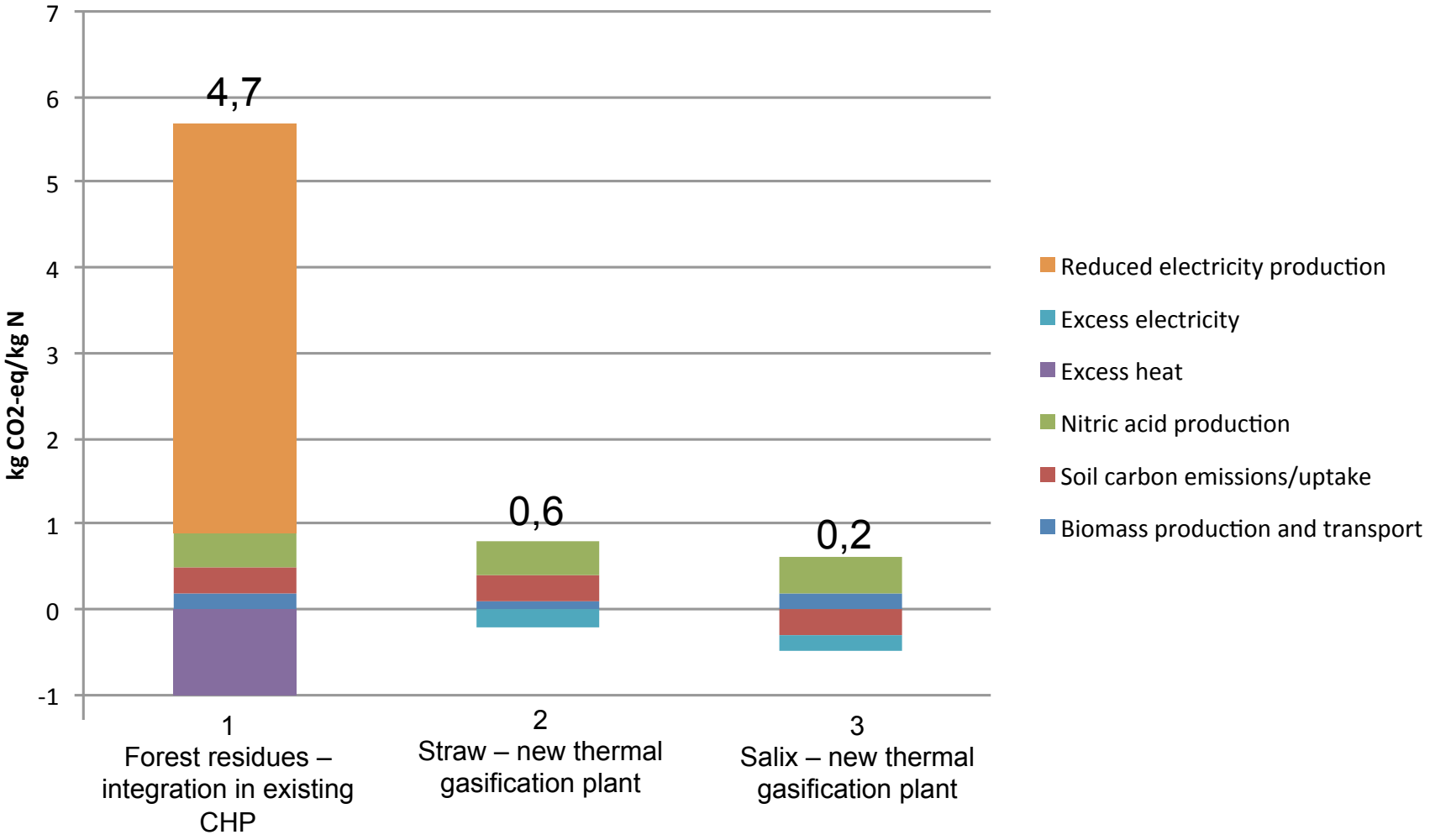



- Production of ammonium nitrate granulates
- Based on gasification and anaerobic digestion
- From Ahlgren (2009)
- Attributional LCA

# CLCA – production of AN from renewables



# CLCA results – production of AN from renewables



# Some summarizing words…

Increasing interest for ammonia and nitrogen fertilizers based on renewables!

Biomass gasification seems like a promising alternative!

But questions remain on technology, scale, feedstock, etc

As with all modelling there are uncertainties, e.g. regarding economy and environmental impact

The next step…

# References


Tunå, P., Hulteberg, C., Ahlgren. S. Techno-Economic Assessment of Non-Fossil Ammonia Production. Submitted to *Environmental Progress & Sustainable Energy*. http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1944-7450/issues

Ahlgren, S., Baky, A., Bernesson, S., Nordberg, Å., Norén, O., Hansson, P.A. 2012. Consequential Life Cycle Assessment of Nitrogen Fertilisers Based on Biomass - a Swedish perspective. *Insciences Journal Climate Change*, 2(4), 80-101. http://dx.doi.org/10.5640/insc.020480

Ahlgren, S., Bernesson, S., Nordberg, A. & Hansson, P.-A., 2010. Nitrogen fertiliser production based on biogas - Energy input, environmental impact and land use. *Bioresource Technology* 101(18), 7192-7195. http://dx.doi.org/10.1016/j.biortech.2010.04.006

Ahlgren, 2009. Crop production without fossil fuel. Production systems for tractor fuel and mineral nitrogen based on biomass. *Doctoral dissertation*. Dept. of Energy and Technology, SLU. Acta Universitatis agriculturae Sueciae vol. 2009:78. http://pub.epsilon.slu.se/2151/

Ahlgren, S., Baky, A., Bernesson, S., Nordberg, Å., Norén, O., Hansson, P.-A. 2008. Ammonium nitrate fertiliser production based on biomass – environmental effects in a life cycle perspective. *Bioresource Technology* 99, 8034–8041 http://dx.doi.org/10.1016/j.biortech.2008.03.041


SLU

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

# Thank you!