Carbon neutral agriculture and landscape

Professor Jørgen E. Olesen

How to manipulate carbon and nitrogen cycles?

AARHUS UNIVERSITY
DEPARTMENT OF AGROECOLOGY

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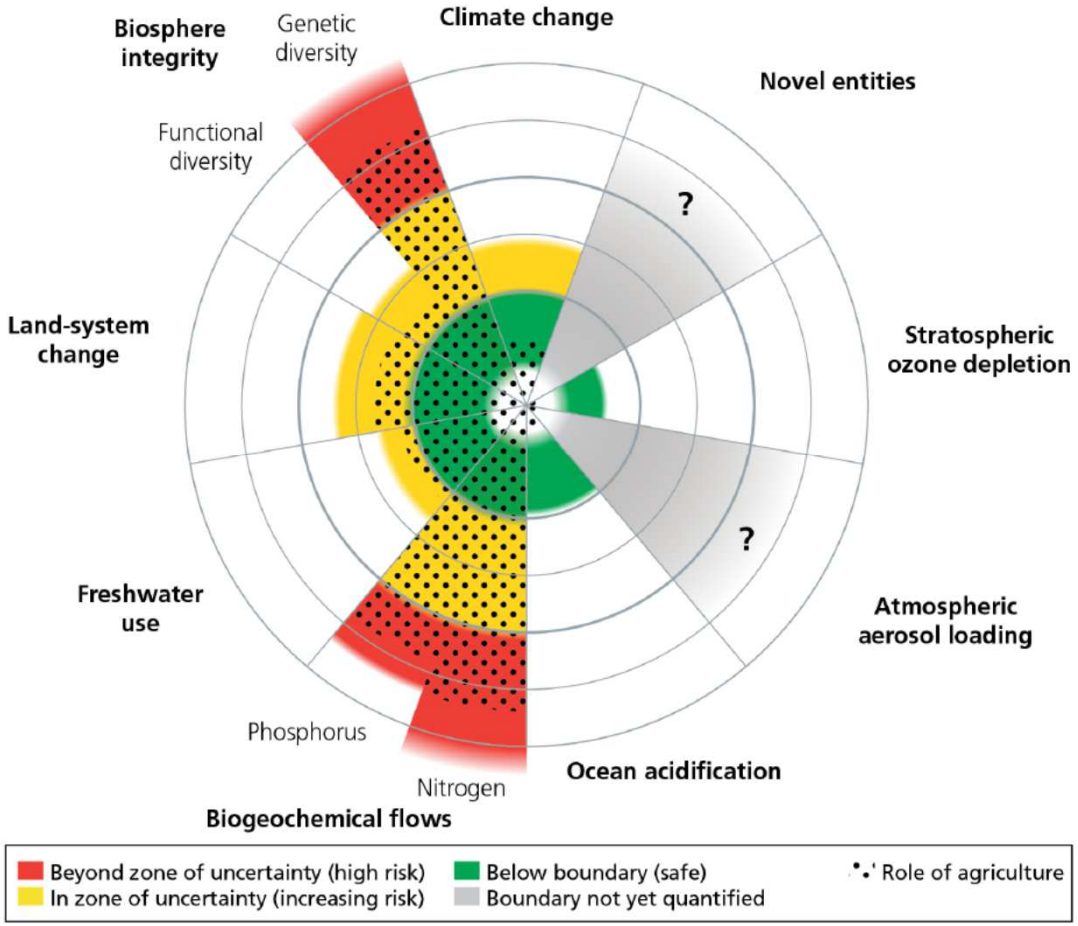
JØRGEN EIVIND OLESEN
SECTION MANAGER, PROFESSOR

iCLIMATE INTERDISCIPLINARY CENTRE FOR CLIMATE CHANGE

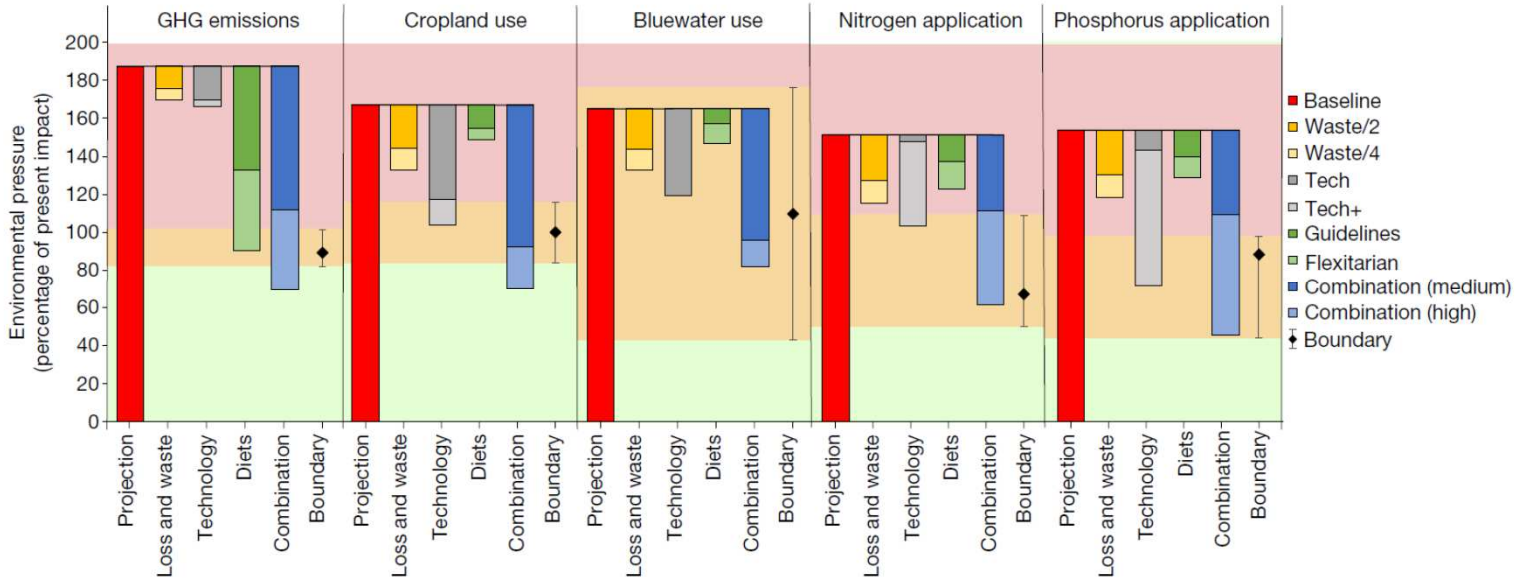
The role of agriculture for planetary boundaries



Campbell et al. (2017)

Solutions for planetary challenges (2050)

Improved agric. technology
Less food waste
Less meat consumption (flexitar)

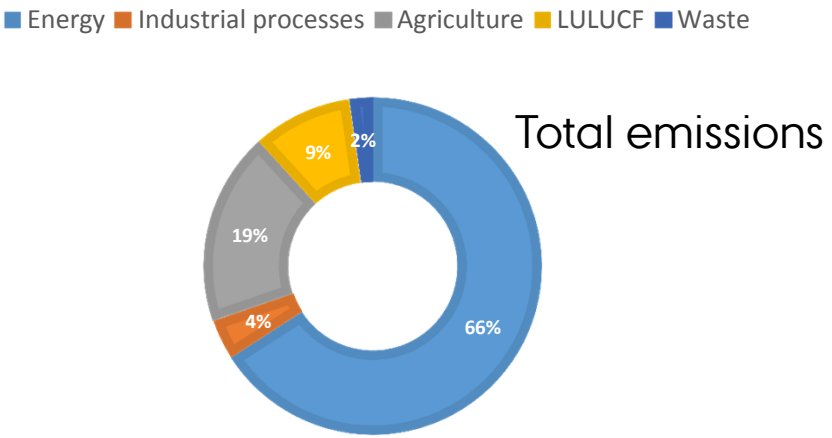


Springmann et al. (2018)

GHG emissions from agriculture in Denmark 2016

National emissions (territorial basis)

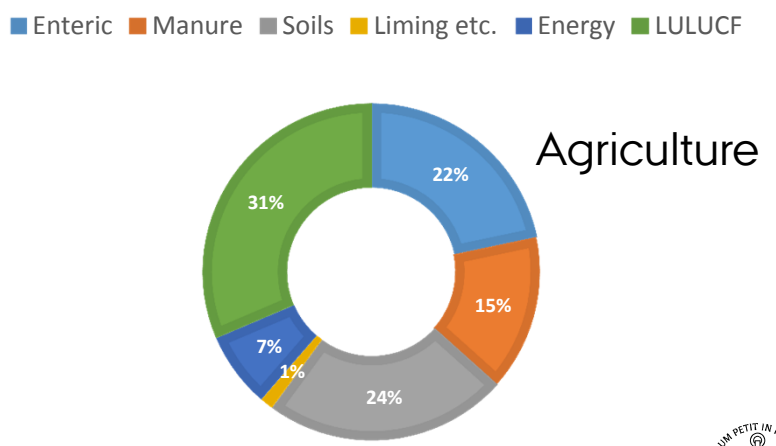
- **Total**: 57.0 Mt CO_2-eq
- Reduced by 24% since 1990 (neutral in 2096)
- **Agriculture + LULUCF**: 16.0 Mt CO_2-eq
- Reduced by 9% since 1990 (neutral in 2290)



Total emissions

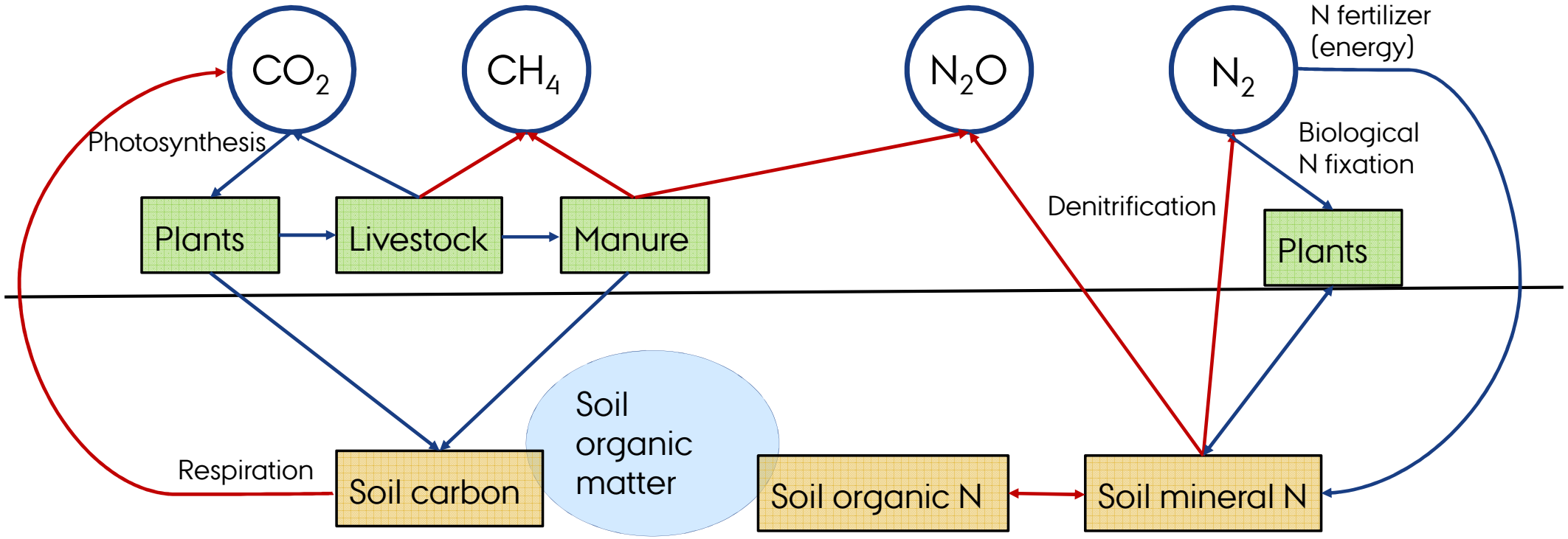
Agricultural emissions (territorial basis)

- Enteric (CH_4 from ruminant animals, cattle)
- Manure (primariliy CH_4 from slurry)
- Soils (N_2O from fertilizers, manure, residues etc.)
- Energy (primarily fuels)
- LULUCF (primarily cultivated peatlands)



Agriculture

GHGs associated with the carbon and nitrogen cycle

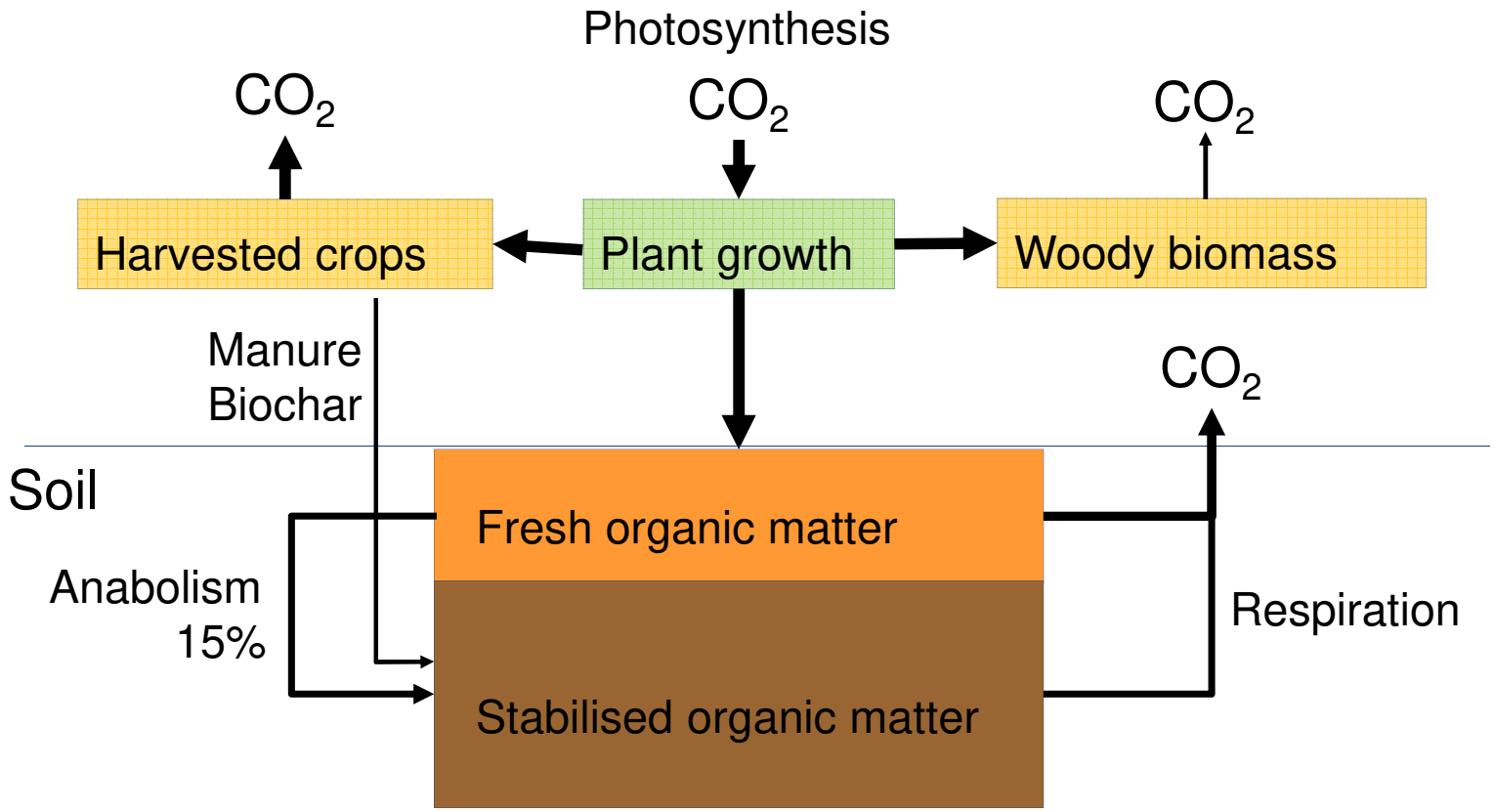


CO_2, CH_4 and N_2O losses are mostly driven by microbiological processes

Reduction of methane and nitrous oxide (estimated potential)

Kilde	mio ton CO2	Pct reduktion	Reduktion
CH4, fordøjelse	2.85	20	0.57
CH4, husdyrgødning	1.31	50	0.66
N2O, HUG udbragt	1.17	20	0.23
N2O, handelsgødnin	1.18	30	0.35
N2O, HUG lager	0.40	50	0.20
N2O, NO3+NH3	1.46	10	0.15
N2O, andet	1.23	0	0.00
Total	9.60	22	2.16

Plant CO_2 uptake and storage in vegetation and soil



Carbon storage: Balance between inputs and respiration

Can agricultural soils store more carbon?

Sufficient measures to enhance soil organic carbon (SOC)?

- Soil carbon is primarily (solely?) enhanced through higher organic matter inputs.
- Competition with demands for biomass (food, feed, fibre, biofuels).

Permanence of soil carbon?

- Existing high carbon pools in peatland soils should be preserved through high water table.
- Measures to maintain C stocks in mineral soils needs to be sustained.

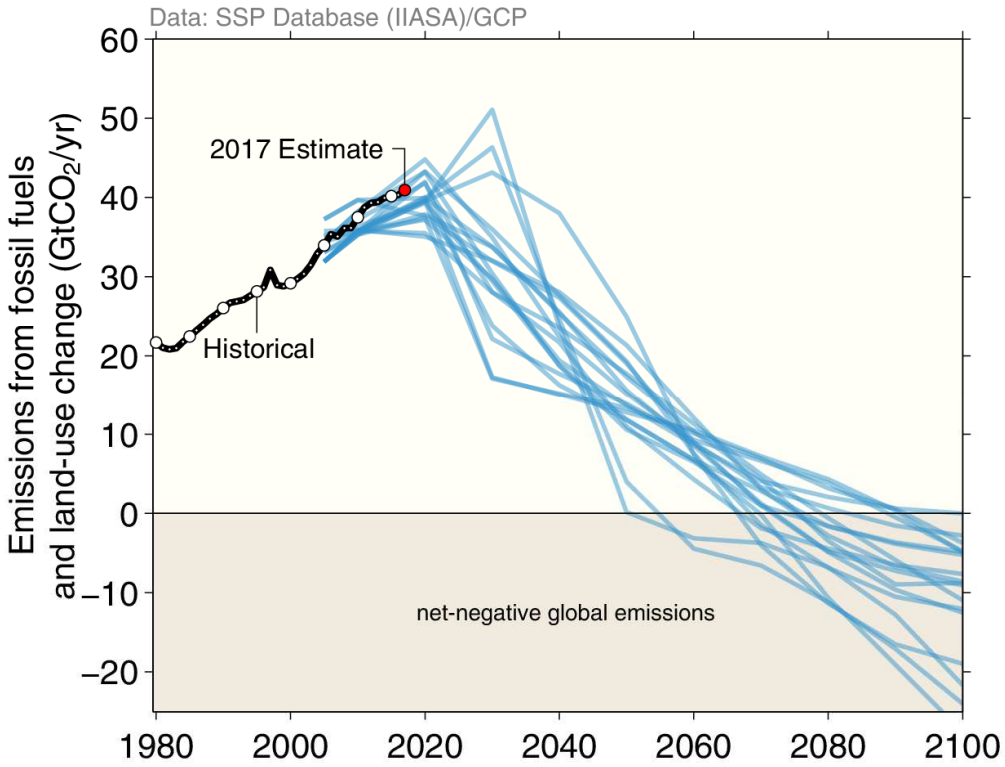
Global warming increases soil carbon decomposition

- Higher temperatures enhance SOC decomposition. A 1 °C increase is estimated to reduce global SOC by 1.6 Gt C/yr.

Overall assessment

- The possibilities for enhancing SOC depends on the balance between enhanced C inputs and enhanced SOC decomposition.
- It will likely be challenging just to maintain current SOC levels.

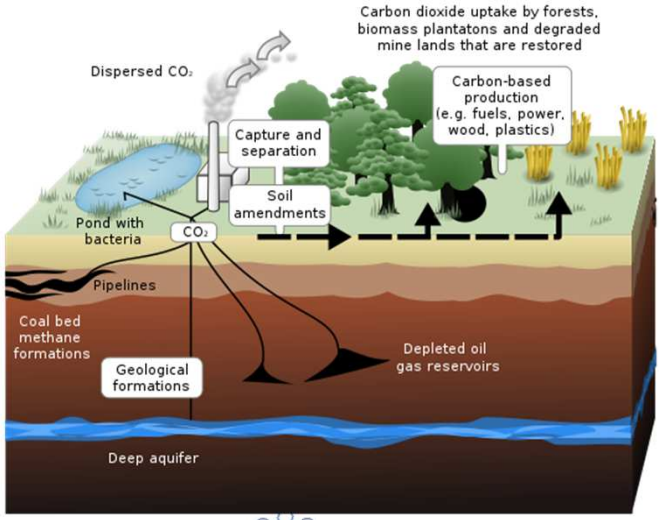
Pathways to 2 degree target



Sufficient emissions reductions can only be achieved with carbon removal (carbon storage).

Point sources (power plants):
- CCS in geological formations
- BECCS: Bioenergy CCS

Atmosphere:
- Storage in vegetation (forest)
- Storage in soils (organic and biochar)



Potential for carbon storage in Denmark

Rewetting of organic soils (peatland)

- Rewetting of peatland in river valleys: 1.500 kt
- Rewetting of all organic soils: 3.400 kt

Grass on the current maize area (green biorefining)

- Grass on maize area (179.000 ha): 650 kt

Straw for biogas in stead of combustion:

- Straw for biogas replacing incineration: 250 kt

Increased area of cover crops:

- Additional cover crops (205.000 ha): 200 kt

Afforestation (depends on time horizon, here 20 years)

- Afforestation (10% of agricultural area): 1.100 kt

Total **5.600 kt**

Challenges and opportunities

- Reducing agricultural production will potentially outsource emissions to other regions (leakage)
- Reducing agricultural GHG emissions is technically difficult (manage microorganisms)
- Enhancing soil carbon
  - Perennial crops
  - Deeper rooted crops
- Need for novel thinking:
  - New agricultural systems (perennial crops, efficient animals, artificial meat and milk)
  - New technologies (microorganisms)
  - New crops (e.g. higher albedo, exudates affecting soil microorganisms)
  - Integrate circular technologies (eg biorefining)