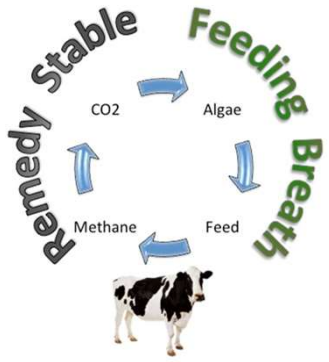

Feeding breath

Circular Stable Design: Integrating Algae as Cow Feed – a Feasibility study

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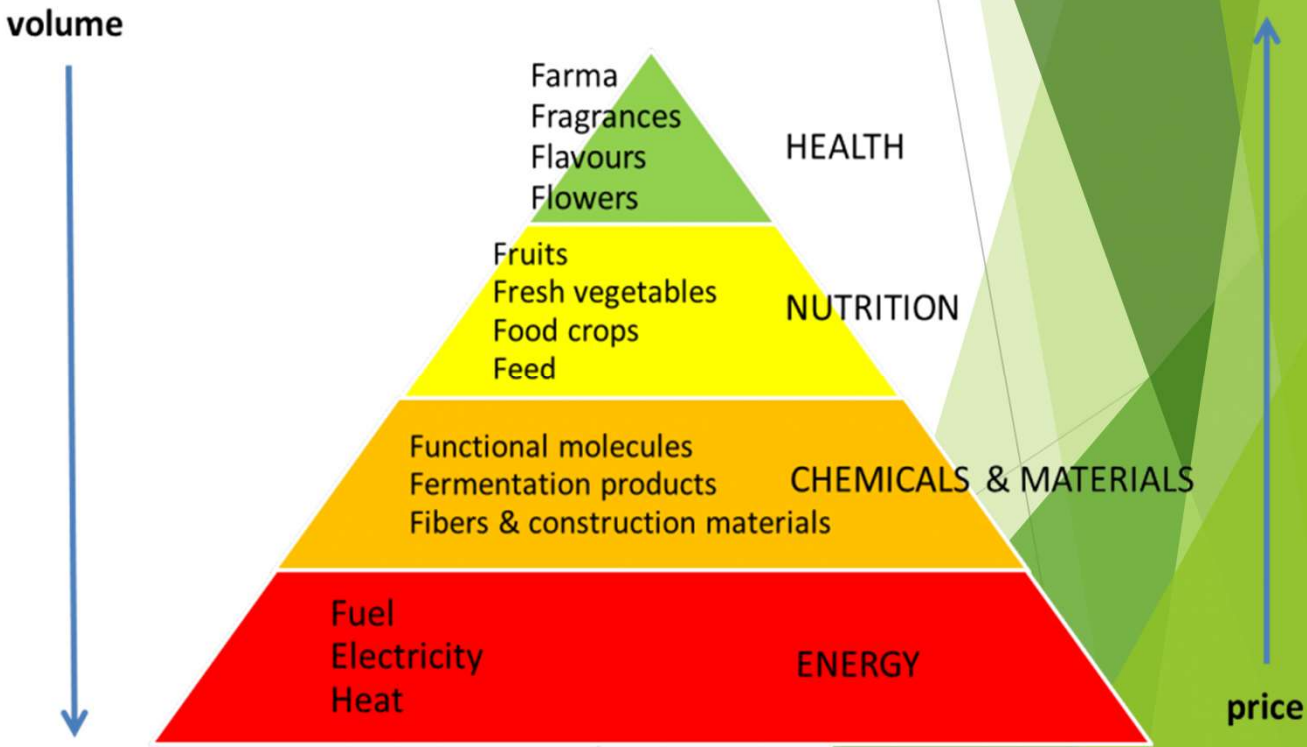
Greenhouse gas emissions

- Methane and carbon dioxide
- REMEDy stable

- Increasing product value

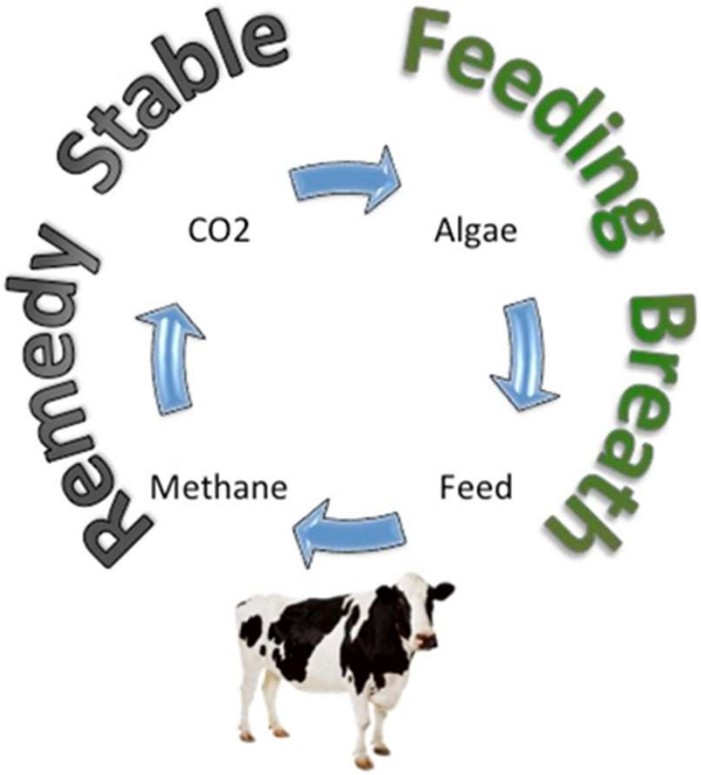


Sustainability of animal feed

- Feed contributes extensively to cost price of milk
- Imported concentrates
- Soy

- Deforestation
  - Decreases biodiversity
  - Enhances greenhouse gas emission
  - Loss of water regulation

Circular system design



- Use of methanotrophic bacteria
- Feeding unprocessed algae

- Uncertainties:
  - Animal health
  - Milk production
  - Palatability
  - Algae species
  - Optimal growing system
  - Cost-efficiency

Goal and structure

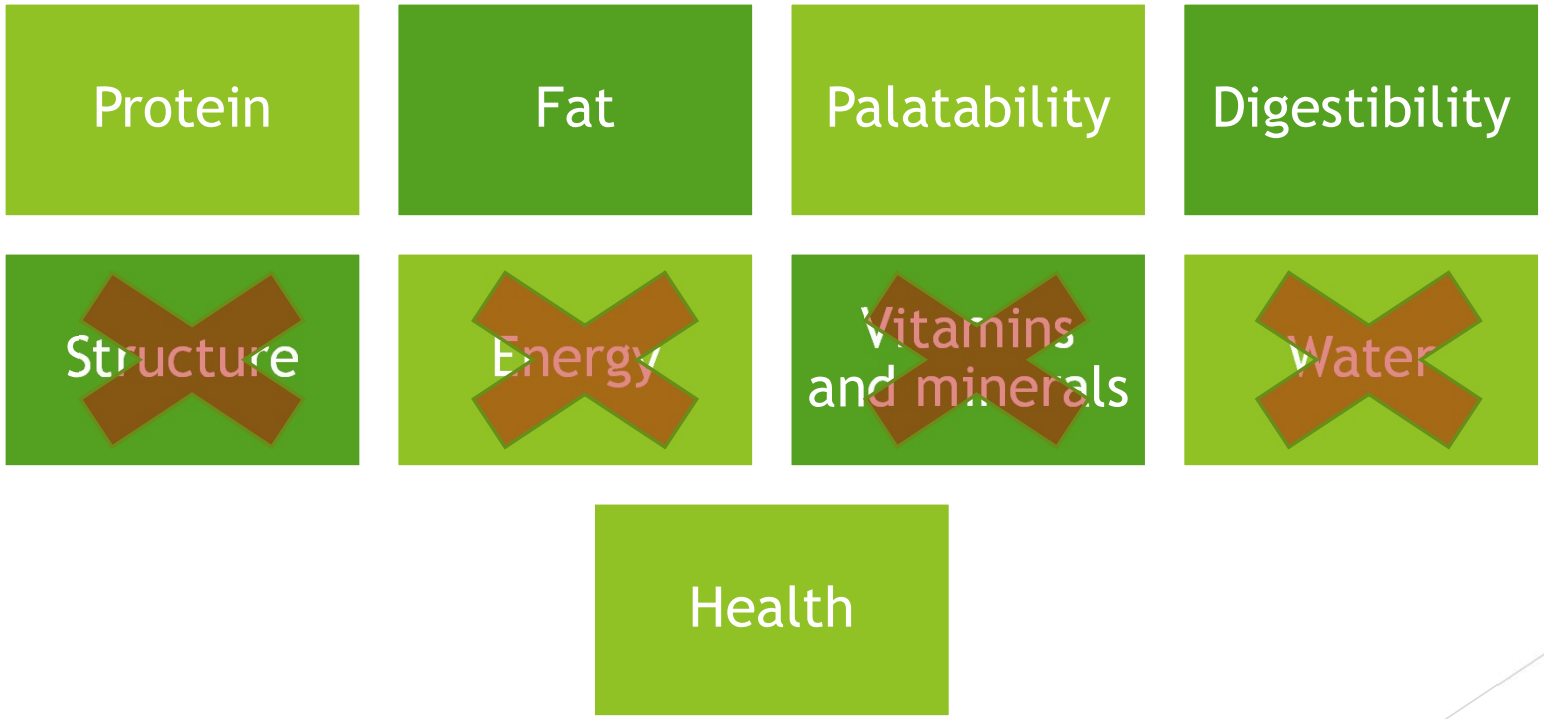
To assess the feasibility of growing algae on methane and carbon dioxide, emitted by dairy cows, and feeding these algae to the cows.

1. Nutritional value of algae
    i. Species pre-selection
2. Methods of growing algae
    i. Second species selection
3. Scenario analysis
4. Conclusion and recommendations

Nutritional value

Algae as feedstuff

Instead of soy

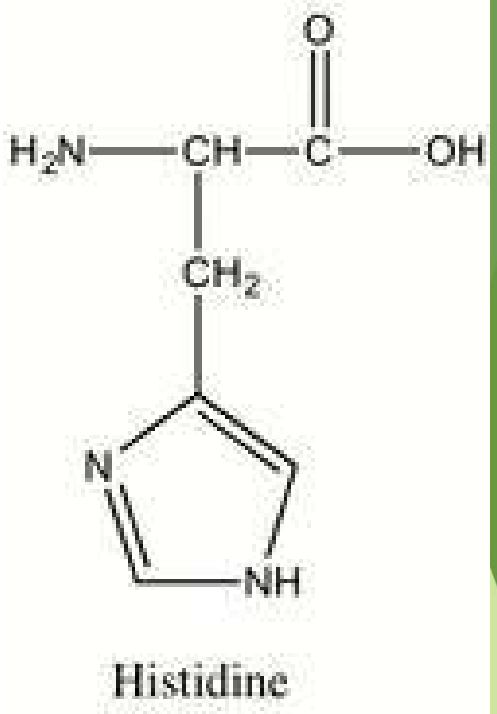


Nutritional value

Protein

- Important for body functions
- Protein rich algae species (>40% DM)
- Aminio acid composition mostly similar
  - Lack of histidine

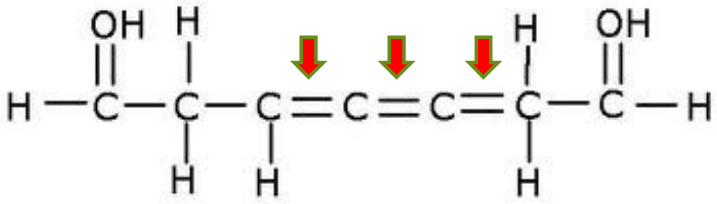
- Milk protein content relatively insensitive
- Roughage:concentrate ratio
  - Not confirmed



Histidine

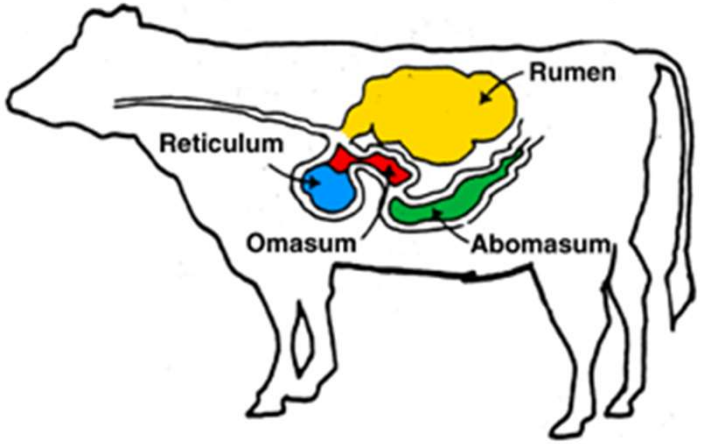
Nutritional value

Fat



Polyunsaturated fatty acid

- Energy source
- Milk fat very senstive
  - Disturbed rumen processes
  - Milk fat depression
  - Milk fatty acid profile
- Algae species low in fat (<10% DM)



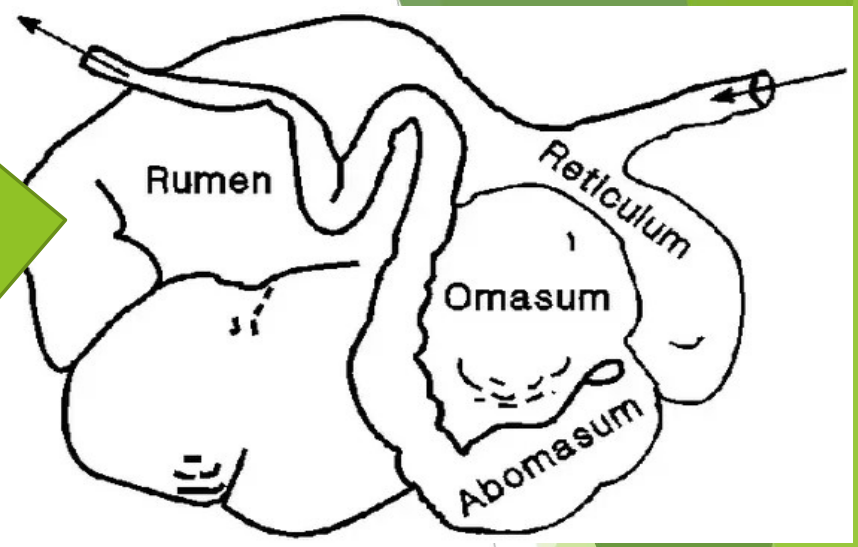
Palatability

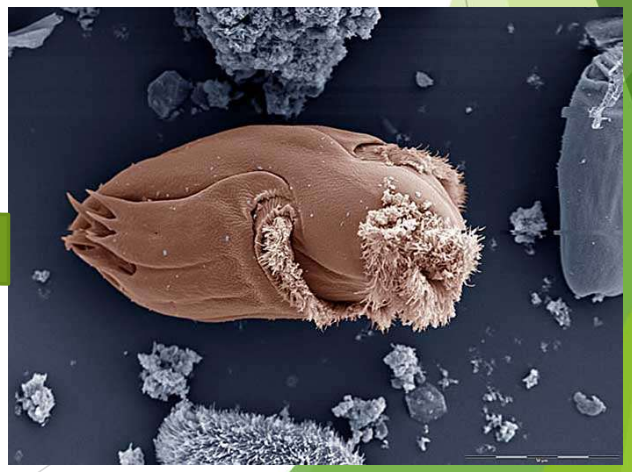
- Cows consume algae
- Sometimes decreased feed intake
- Sometimes decreased milk yield
- → Diet fat content

- Wet algae
  - In the water?

Digestibility

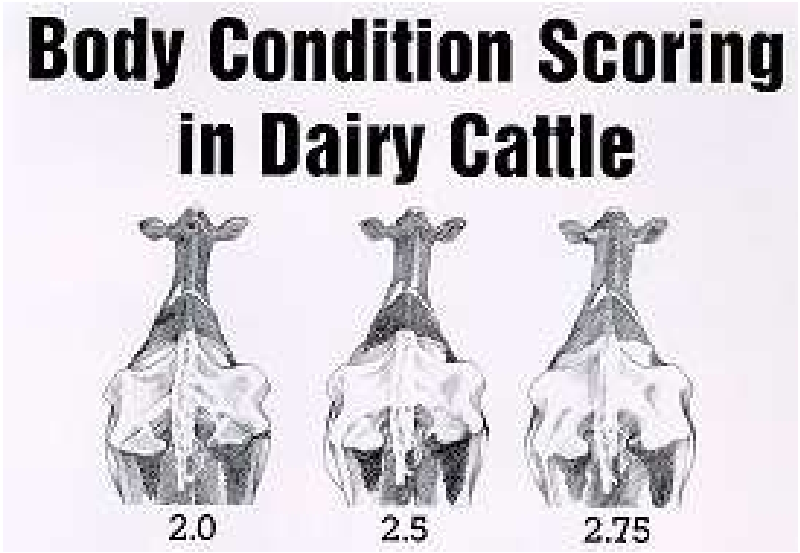
- Thickness and lignification of algal cell wall
- Fat content of algae
- Toxicity





Health

- No effect on body weight and condition
- No health concerns observed

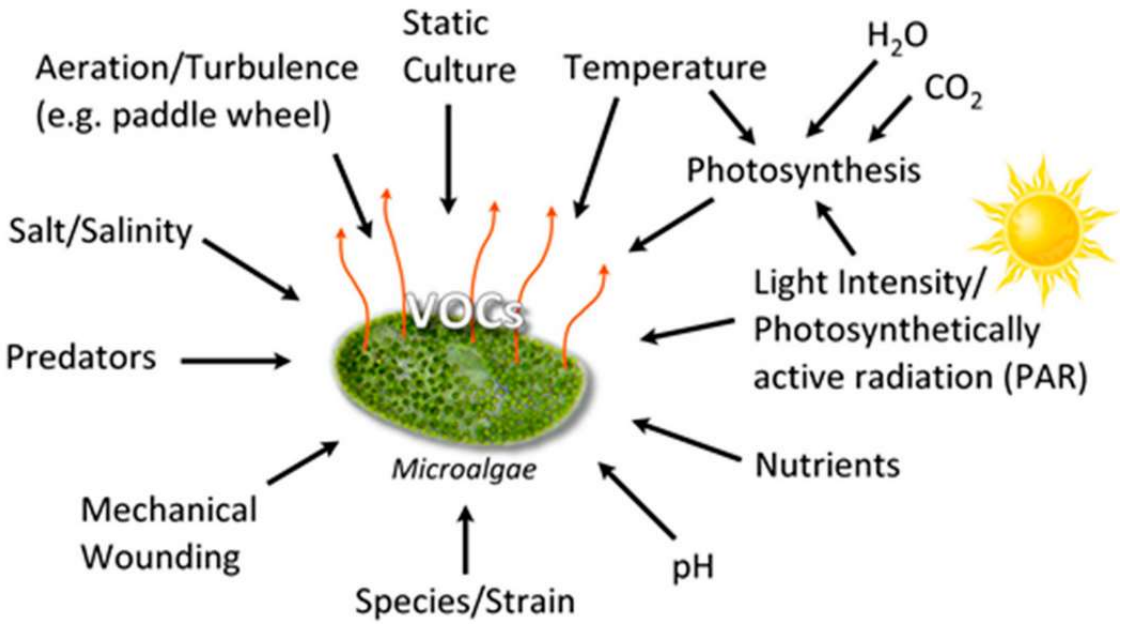


Selecting algae species

Criteria: Protein >40% DM & Fat <10% DM

Species name	Protein content (% DM)	Fat content (% DM)
Anabaena cylindrical	43-56	4-7
Aphanizomenon flos-aquae	62	3
Arthrospira / Spirulina platensis	46-65	4-9
Arthrospira / Spirulina maxima	45-71	4-7
Chlorella pyrenoidosa	57	2
Dunaliella salina	57	6
Scenesmus quadricauda	47	1.9

Growing Algae - Inputs



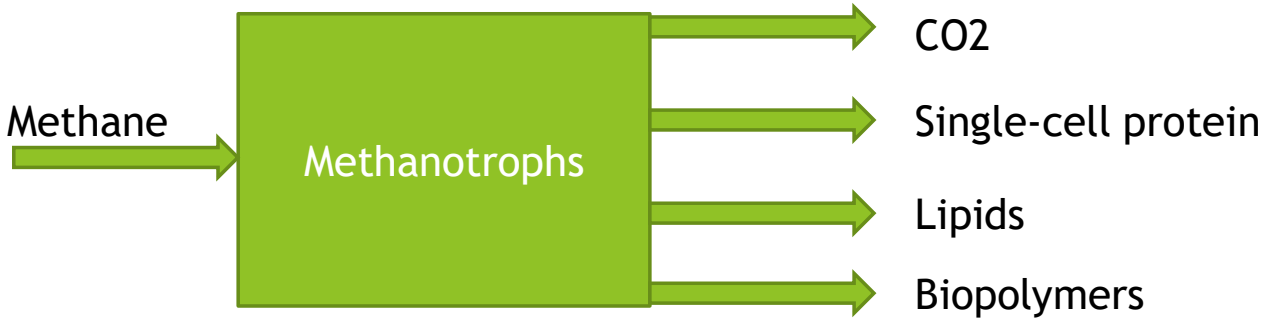
	Temperature	pH	Salinity
	[°C]	[-]	[%]
Spirulina platensis	25-30	8.5-10	20-24
Spirulina maxima	30-35	9	20-24
Chlorella pyrenoidosa	37	6.5-7.15	2.5
Dunaliella bioculata	-	-	20-24

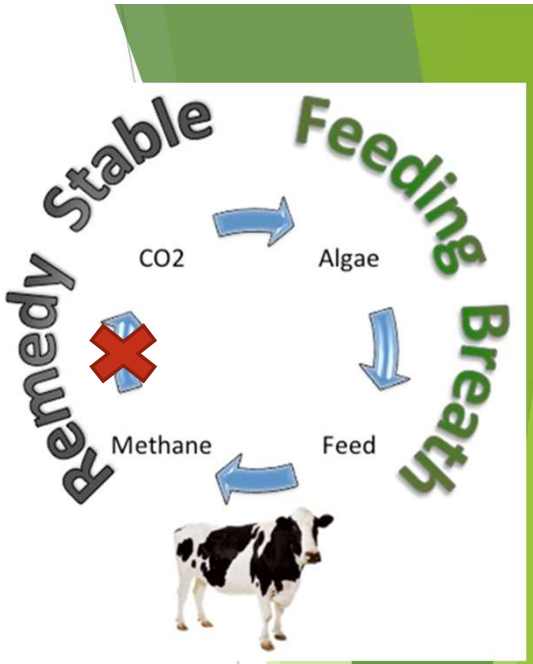
Methanotrophs

Needed for algae growth: 10.7 kg CO2 (per cow per day)

CO2 respired: 11.88 kg CO2 (per cow per day)

CH4 converted into CO2: 0.63 kg CO2 (per cow per day)





Growing Algae - Photo Bioreactors

- Open/closed
- Vertical/horizontal
- Panels/tubes

Raceway pond

Horizontal tubular PBR

Flat panel PBR

Vertical tubular PBR

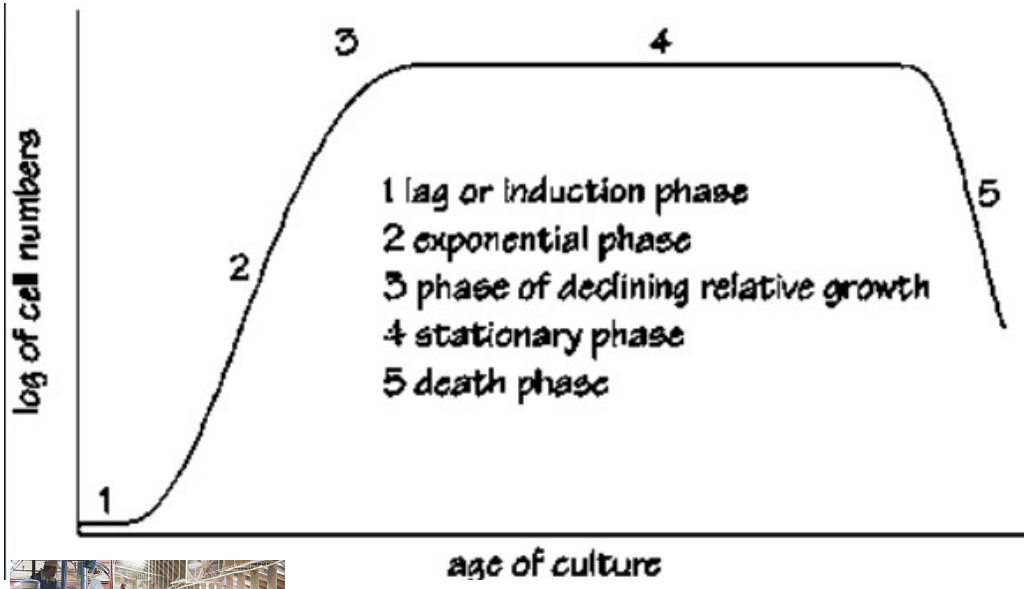
Growing Algae – Harvesting & Feeding

- Harvesting depends on requirements of end product

- Dried pellets
- Drinking water
- Mix wet algae in the ration

Growing Algae – Operation strategy

- Batch
- Continuous
- Semi-continuous



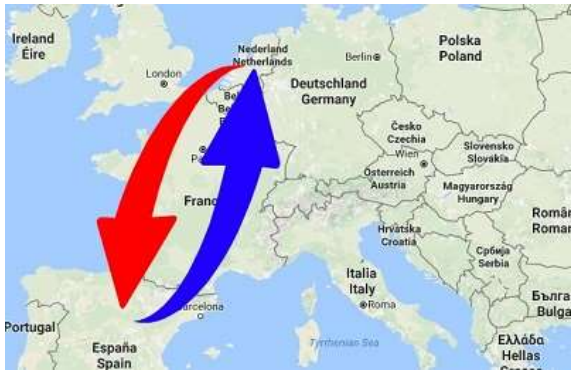
Continuous

Semi-continuous

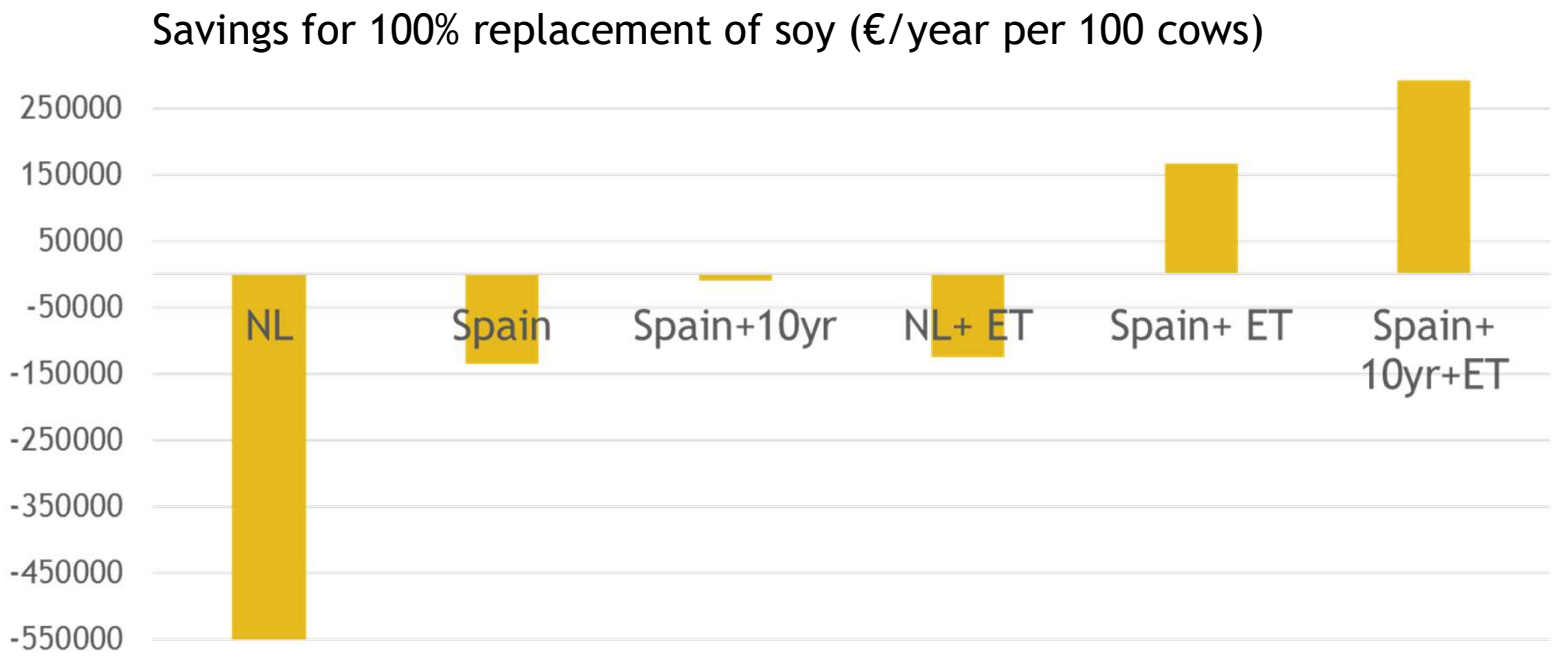
Scenarios and assumptions

- Replace 100% of the soy with year round production
- Future prediction (technological development)
- Ecological tax → Price of soy increases

NL - Current	Spain – Current	Spain + 10year	NL+ Ecological Tax	Spain+ Ecological Tax	Spain + 10year + Ecological Tax



Scenario analysis – Results



Conclusion

- Not feasible in current situation in NL
- To make it feasible
  - Soy price increase extremely
  - High environmental taxes
  - Efficiency of growing system improves radically

Recommendations

- Use *Spirulina platensis*
- Use flat panels
- Move towards the equator

- Further research on
  - shortage of amino acid histidine
  - palatability of algae in water (and total mixed ration)
  - alternative uses for methane
  - development of production systems
  - harvest method based on feeding method
  - recycling cow heat